1984-03

LAMPS MK III pack-up kit sparres selection as depicted by the Availibility Centered Inventory Model (ACIM).

McDonell, James A.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

LAMPS MK III PACK-UP KIT SPARES SELECTION

AS DEPICTED BY THE

AVAILABILITY CENTERED INVENTORY MODEL (ACIM)

by

James A. McDonell

March 1984

Thesis Advisor: Dan C. Boger

Approved for public release; distribution unlimited

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) LAMPS MK III Pack-up Kit Spares Selection as Depicted by the Availability Centered Inventory Model (ACIM)		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1984
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James A. McDonell		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE March 1984
		13. NUMBER OF PAGES 107
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Availability Centered Inventory Model (ACIM), LAMPS MK III

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis presents an overview of the Availability Centered Inventory Model (ACIM). Information and analyses are provided for the system and support hierarchies, rudimentary assumptions, and the maximum availability calculation envisioned by ACIM. A discussion on the procedures used to develop a LAMPS MK III helicopter availability-centered allowance list is presented. This allowance list is then used as a basis for selection of LAMPS MK III Pack-up Kits (PUKs). The PUKs selected are analyzed via the statistics provided by ACIM

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

in its Statistical Summary Report. The objective of this analysis is to provide an understanding of some of the strengths and weaknesses of ACIM when it's used as a decision aid or analysis tool.

LAMPS MK III Pack-up Kit Spares Selection as Depicted by the Availabiliy Centered Inventory Model (ACIM)

by

James A. McDonell
Lieutenant, United States Navy
B.S., State University of New York at Binghamton, 1977

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 1984

ABSTRACT

This thesis presents an overview of the Availability Centered Inventory Model (ACIM). Information and analyses are provided for the system and support hierarchies, rudimentary assumptions, and the maximum availability calculation envisioned by ACIM. A discussion on the procedures used to develop a LAMPS MK III helicopter availability-centered allowance list is presented. This allowance list is then used as a basis for for selection of LAMPS MK III Pack-up Kits (PUKs). The PUKs selected are analyzed via the statistics provided by ACIM in its Statistical Summary Report. The objective of this analysis is to provide an understanding of some of the strengths and weaknesses of ACIM when it's used as a decision aid or analysis tool.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

I take this opportunity to acknowledge and thank Dr. Peter Evanovich of the Center for Naval Analysis (CNA) who provided me with an enlightening introduction into the theory of the Availability Centered Inventory Model. Dr. Evanovich was also of great assistance in helping me locate source documents which aided my research.

I would also like to acknowledge and thank my wife, Stacey, for the many hours of typing assistance she provided.

I. INTRODUCTION

The Light Airborne Multi-Purpose (LAMPS) MK III is an aircraft developed principlely for use as an airborne extension of smaller surface combatants' mission capabilities. Therefore, the LAMPS MK III (designated the SH-60B) is tasked to perform many missions. Its primary mission is Anti-Submarine Warfare (ASW). Its secondary mission is Anti-Ship Surveillance and Tracking (ASST). The other missions which LAMPS MK III must perform include Search and Rescue (SAR), medical evacuation, VERTical REPlenishment (VERTREP), and communication relay.

The missions that LAMPS MK III can potentially be tasked with dictate that a high state of operational availability be maintained. The high operational availability needed was shown to be unsupportable by standard Fleet Support Improvement Program (FLSIP) methods. Therefore an alternate method for sparing the LAMPS MK III was sought.

In March 1981, after various sparing concepts were explored, the Chief of Naval Operations (CNO) directed the use of the Availability Centered Inventory Model (ACIM) for LAMPS MK III Pack-Up Kits. A Pack-Up Kit (PUK) can generally be considered as an aviation-oriented collection of spare parts that is located aboard a host ship. The details of the LAMPS MK III Pack-Up Kit are discussed later. The Availability Centered Inventory Model (ACIM) was designed and developed principally by Mr. Andrew Clark of CACI-Inc. Federal. It is an extension and generalization of such previously developed provisioning models as METRIC (Multi-Echelon Technique for Recoverable Item Control), MOD-METRIC (Model for a Multi-Item, Multi-Echelon, Multi-Indenture Inventory System) and LSEE (Logistic Support Economic Evaluation).

The objective of ACIM is to provide a provisioning model based upon an optimal inventory policy. The objective function may be defined as one that determines the least cost of spares stockage to attain a specified level of operational availability, or conversely, the objective function may be to provide the most operational availability for a predetermined level of inventory investment. The most recent version of ACIM, version 2.0, allows the user compare the results of the Availability Centered Inventory Rule (ACIR) with any one of seven alternative stocking policies.

The purpose of this thesis will be to examine the use of ACIM in the context of LAMPS MK III PUK sparing. First, the underlying supply and system structures envisioned by ACIM are introduced in Chapter II. An overview of ACIM implicit and explicit assumptions are reviewed; then the availability calculations are developed and the effects of the assumptions on these calculations are discussed. The input data required to run the model, the model structure and the reports generated by ACIM also are presented in Chapter II.

Chapter III discusses the limitations of of ACIM for sparing the LAMPS MK III PUK and discusses the specific allowance list used in this study. Chapter IV provides an analysis of the PUK spared by ACIM. Sensitivity analysis is performed on various model parameters and attributes. This thesis does not propose how to enhance the viability of the ACIM calculations but it does present ACIM behavior when sparing the LAMPS MK III PUK in a single-site, single-echelon environment. Attention is drawn to some strengths and weaknesses in using ACIM as a decision aid or analysis tool. Conclusions from this analysis are presented in Chapter V.

II. AVAILABILITY CENTERED INVENTORY MODEL

The model utilized in this thesis is the Availability Centered Inventory Model (ACIM), version 2.0, developed by CACI-Inc Federal and implemented by Henry J. Watras for use on the Naval Postgraduate School IBM 3033.

A. INTRODUCTION

ACIM is a computer model written in PL/1 that can be used to calculate steady-state, optimum spare parts inventory requirements for all items in a multi-indentured system at designated stockage locations throughout either a multi-echelon or single-echelon supply support system. This technique, referred to as the Availability Centered Inventory Rule (ACIR), determines stockage amounts such that a given level of equipment operational availability is attained at least cost in terms of inventory investment, or conversely, determines maximum operational availability from a given fixed inventory investment.

The model also has the ability to compare ACIR stockage policy to one of the following stockage policies:

(1) Maintenance Criticality Oriented (MCO) Consolidated Allowance List (COSAL) policy;

(2) .25 FLSIP COSAL policy[1] ;

----

[1]FLSIP is an acronym for Fleet Support Improvement Program. The .25 reflects the level of demand needed to be established as .25 per year, or .0625 per quarter, in order to stock an item. If demand per quarter is greater than or equal to 1.0, then stockage is established for a 90 percent protection against stockout of the item at that site. When the quarterly demand rate at the site is between .0625 and 1.0, then the Minium Replacable Unit (MRU) of the item is stocked at the site.

(3) Center for Naval Analyses (CNA) Modified COSAL policy;

(4) User-defined protection policy against individual item stockout;

(5) User-specified item inventory levels at the various supply sites;

(6) Department of Defense Instruction 4140.42 provisioning policy; and

(7) Uniform Inventory Control Point wholesale policy.

The current version of ACIM, if used in a multi-echelon support system, is capable of computing stockage levels for operational units as well as for intermediate and depot maintenance facilities that support the equipment. The maximum number of items and stockage locations that can be considered depends on the amount of random access memory of the computer used. The items stocked may be consumable, repairable, or any mixture thereof. Each item is treated as being unique; for instance, if the same item appears more than once in the input, each appearance is treated as if it were a different item insofar as model operation and stockage requirements are concerned.

Even though the model is capable of recognizing interrelationships of equipment parts in a hierarchical breakdown (multi-indentured) structure in a multi-echelon supply support system, these features need not be fully exercised in a given application.

B. DESCRIPTION OF SYSTEM AND SUPPLY ORGANIZATION

1. Multi-Indentured System

The ACIM model uses a hierarchical breakdown structure to describe a system.[2] This is usually referred to as a multi-indentured system.

In Figure 2.1 the equipment (system) is theoretically composed of the aggregation of all items from the

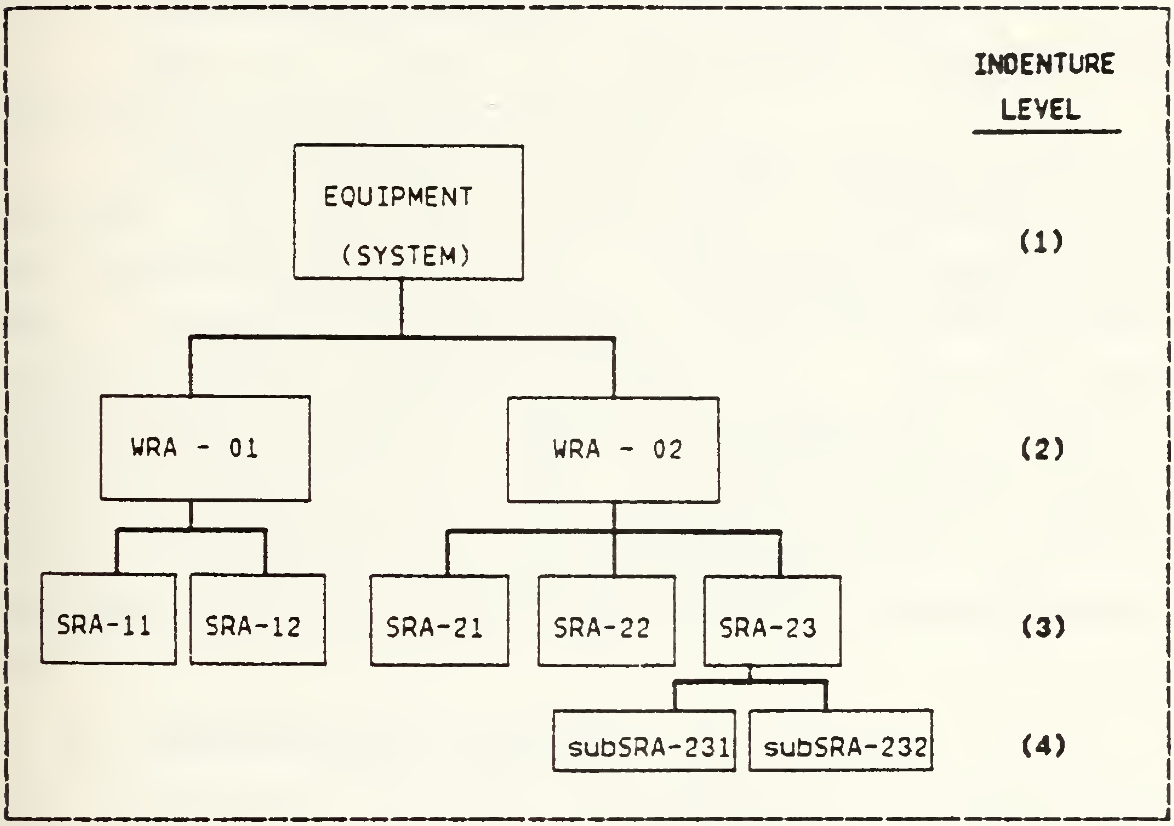

Figure 2.1 Multi-indenture Structure Employed by ACIM.

second indenture level. An item in the second level of indenture is referred to as a Weapon Replaceable Assembly (WRA). These WRA's consist of lesser components called Shop

---

[2]The terms system and equipment are used interchangeably throughout this article.

Replaceable Assemblies (SRA). The indenture structure continues to break the system down into sub-SRA's, sub-sub-SRA's, et cetera, until the system is described to the level of detail defined by the user's data.

Inherent in this system portrayal is the assumption that a failure anywhere within the structure creatures a failure (down-time)[3] for the entire system. This equates to a system constructed in series.

2. Multi-Echelon Support

ACIM is capable of considering a single-[4] or multi-echelon support organization.

Figure 2.2 shows a typical supply support system in the Navy. If the single echelon mode is selected then ACIM just stocks the lowest echelon. The highest echelon in the Navy, the site originating supply support or spares provisioning, is not included in Figure 2.2 . The site which handles this provisioning function is usually one of the two Inventory Control Points (ICP). The Aviation Support Office (ASO) in Philidelphia, Pa. generally manages aviation related spare parts while the spare parts for ships are managed by the Ships Parts Control Center in Mechanicsburg, Pa.

3. Level-of-Repair Analysis

The glue that holds the maintenance activities and the supply activities together is the Level-Of-Repair (LOR) analysis. As stated in MIL-STD-1390B, the purpose of LOR is to establish a least-cost feasible repair or discard decision alternative when performing system maintenance actions

---

[3]The concept of down-time will be discussed at length later in the chapter.

[4]A single-echelon support system, in Naval Aviation terminology, is called organizational level.

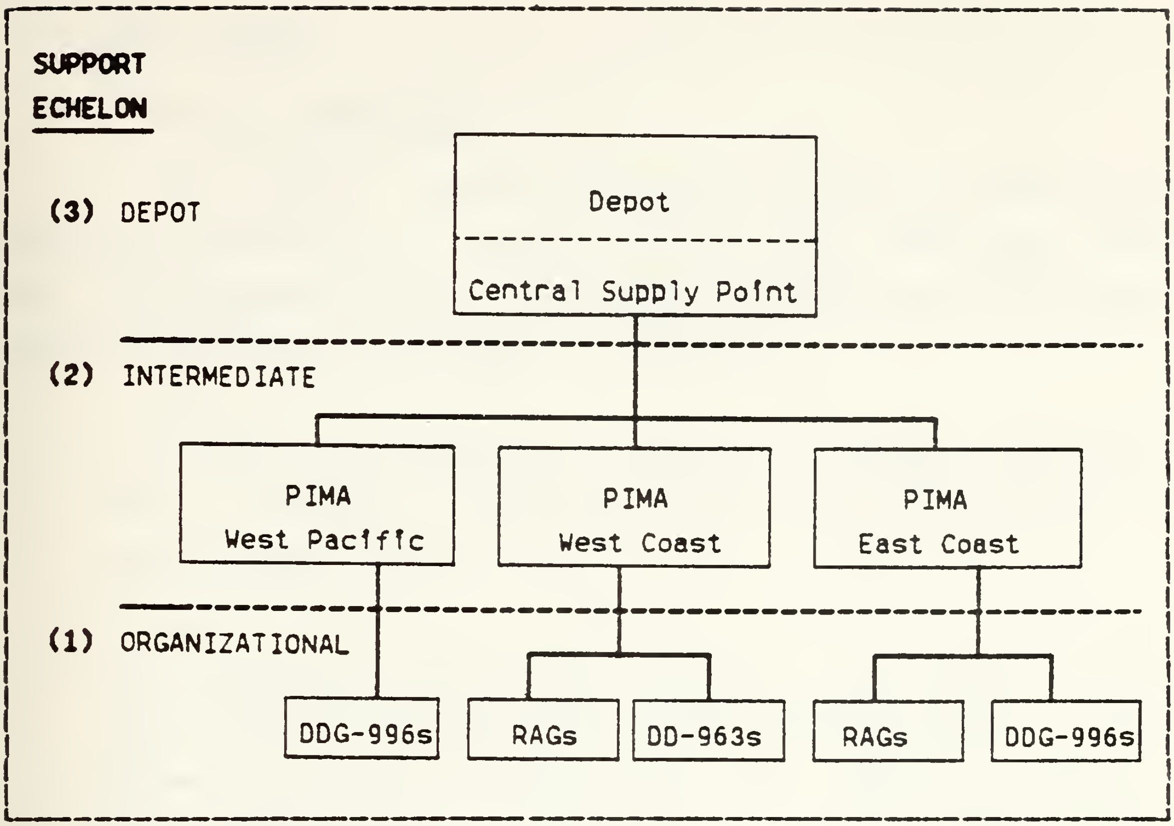

Figure 2.2 Example Multi-Echelon Support Structure.

and to influence system design in that direction. Measures of system effectiveness such as operational availability are not included in LOR analysis as policy considerations.

The major outcome of LOR analysis, in Navy terminology, is the development of the Source, Maintenance, and Recoverability (SM&R) codes. The SM&R codes reflect policy regarding whether an item should be discarded or repaired at the depot, intermediate, or organizational level. The first two characters of this five character code are not used by ACIM. The third character specifies the lowest echelon of maintenance authorized to remove and replace an item. The fourth character specifies the lowest echelon authorized to repair the item. If the item is to be discarded, the fifth character designates the echelon level which may dispose of it.

C. MODEL THEORY

1. Model Assumptions

In a model, assumptions must be made to squeeze the infinite variables of reality into a finite set with which one can reasonably deal. Principle assumptions and limitations of ACIM are summarized as follows:

1. Parts are organized within a system (equipment) with a top-down breakdown that can be viewed as a network (see Figure 2.1).

2. Stockage/maintenance facilities are organized in a hierarchical structure according to supply/maintenance flows which can be represented as a network similar to the example given in Figure 2.2 . Each facility has a colccated maintenance and supply capability. Indenture levels in the support hierarchy are referenced as 'echelons' according to normal supply terminology. This network assumption precludes lateral resupply at a given hierarchy [Ref. 1].

3. All stockage locations use a continous review, one-for-one ordering policy. This means each time a failure (demand) occurs the support echelon is put into motion.

4. External demands upon supply are stationary and compound-Poisson distributed. Therefore, systems are assumed to operate at a constant rate over a reasonably long period of time.

5. Mean Time To Repair (MTTR) items is defined as a constant by an input parameter and includes all equipment down times that are not supply related.

6. Average turn-around-time for each repairable item assumes that subparts needed for repair are available.

7. Component failures are considered to be independent of each other.

8. No further demands for parts can occur when one or more systems are unavailable. This means that when a failure occurs at a site then all equipments at that site can not generate demands until the degraded equipment is repaired. This is roughly the equivalent of having all systems wired together in series.

9. ACIM assumes that systems are operated only at the lowest echelon.

2. Development of the Maximum Availability Calculation

ACIM implements a basic definition of operational availability, A_o ,as:

$$A_o = \frac{\text{UP-TIME}}{\text{UP-TIME} + \text{DOWN-TIME}} \quad . \quad \text{(eqn. 2.1)}$$

When this defintion is used on a system such as an aircraft, the terms up-time and down-time can be misleading. If one considers up-time to be the time periods for which an

aircraft is Full Mission Capable (FMC), then the aircraft is considered down whenever it is less than FMC even though the aircraft may actually be operating with degraded performance (and possibly accumulating more component failures). This model ancmoly will be discussed in more detail later.

Up-time is described by the term, Mean-Time-Between-Failure (MTBF). Down-time is characterized by two basic quantities: 1) Mean-Time-To-Repair (MTTR) the component and 2) Mean-Supply-Response-Time (MSRT). MTTR is the average, actual amount of time needed for fault isolation, removal, and replacement of a discrepant Weapon Replaceable Assembly (WRA) or Shop Replaceable Assembly (SRA). This tacitly assumes the requisite parts are immediately available when maintenance is being performed. MSRT is considered to include Order and Ship Time (O&ST) as well as expected delays due to shortages at higher echelons of support. Graphically, this is represented in Figure 2.3.

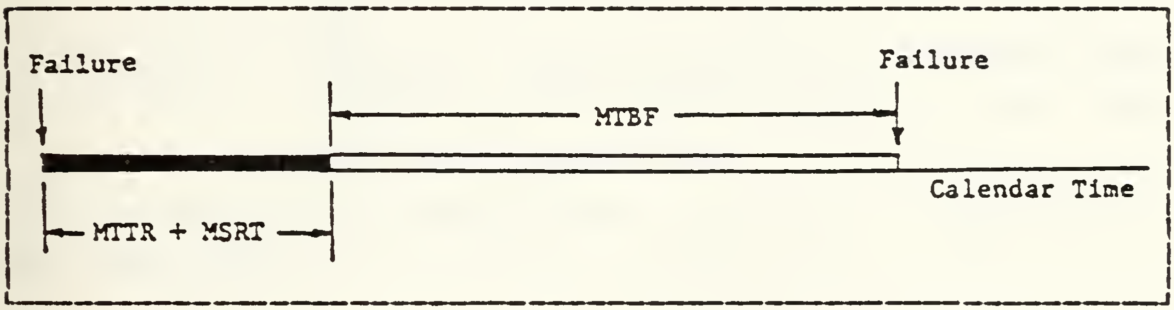

Figure 2.3 Failure and Repair Cycle.

The definition of A_o can therefore be written as

$$A_o = \frac{MTBF}{MTBF + MSRT + MTTR} \quad . \qquad \text{(eqn. 2.2)}$$

ACIM uses MTBF and MTTR (measured in days) as inputs which are subsequently held constant. The MSRT factor is the only one dependent upon stockage postures and is therefore the one that is changed by the model to achieve a given value of A_0 [Ref. 2]. As is seen in equation 2.2, the smaller the MSRT the better availability becomes. However, minimization of MSRT is close to, but <u>not</u> equivalent with, maximization of A_0 [Ref. 3].

MSRT represents the expected delay time for a given site to receive an item through the echelon support structure after a demand[5] occurs. ACIM calculates MSRT as:

$$MSRT = \frac{1}{\lambda} \sum_{X=S}^{\infty} (X-S) * Pr(X;\lambda T) \qquad \text{(eqn. 2.3)}$$

where:

λ = mean demand rate of the item;

S = initial stock level of the item at the site; and

$Pr(X;\lambda T)$ = Poisson, Negative Binomial or Normal[6] probability of X units of the item being demanded during time T.

T is the mean stock replenishment time and is calculated by the equation:

$$T = Pa*(R+R') + (1-Pa)*(L+L') \qquad \text{(eqn. 2.4)}$$

where:

---

[5] A failure is assumed to create an immediate demand, and the terms are considered interchangeable.

[6] The distribution used for backorder days depends upon the mean and variance of the parts selected.

Pa = the probability that the item is not repairable;

R = the average supply lead time from the next higher supply source;

R' = the additional resupply time if the item is not in stock at the next higher echelon;

L = local repair cycle assuming the repair parts are in stock;

L' = extra repair time required if repair parts are not immediately in stock.

To arrive at a system MSRT at a particular site, a weighted sum involving failure rate values and the MSRT at the site for the first indenture level is used. The MSRT for the first indenture level is calculated as a function of repair cycle time, MSRT for lower indentured items, and MSRT for the item itself from higher echelon support facilities.

For equations 2.3 and 2.4, Pa, R, and L are inputs to the model and are held constant. The other parameters in these equations are expected values determined by ACIM.

If one divides the numerator and denominator of the right side of equation 2.2 by MTBF it yields:

$$A_o = \frac{1}{1 + (MSRT + MTTR)/MTBF} \qquad \text{(eqn. 2.5)}$$

Equation 2.5 calculates A_o for a single site; if operating N identical systems the computation is:

$$A_o = \frac{1}{1 + N*(MSRT + MTTR)/MTBF} \qquad \text{(eqn. 2.6)}$$

The reciprocal of MTBF yields, for the equipment or component under scrutiny, the Failure Rate (FR). If MTBF is measured in hours, the FR thus defined is measured in units of failures per hour. To express FR as a daily rate one multiplies by 24 hours as shown in equation 2.7.

$$FR = \frac{24 \text{ hours}}{MTBF} \qquad \text{(eqn. 2.7)}$$

As a proxy for MTBF, ACIM utilizes the input item labeled Best Replacement Factor (BFR). The Standard Data Element Dictionary [Ref. 4] defines BRF as the total annual replacement for the item divided by the item population. Each component considered by ACIM has its associated BRF given via input item data. To arrive at a System BRF (SBRF) ACIM uses equation 2.8.

$$SBRF = \sum_{i=1}^{M} (POP_i * BRF_i) \qquad \text{(eqn. 2.8)}$$

where: BRF_i = the BRF of component i.

POP_i = the population of component i on the system, (e.g.) if component i of the system were a tire and that system needed 4 identical tires then, POP = 4;

M = total number of system components.[7]

The daily failure rate for a system, as defined by equation 2.7, can be equated to SBRF as follows:

----

[7]The terms component and item are used interchangeably in this thesis.

$$FR = \frac{24 \text{ hours}}{MTBF} = \frac{SBRF}{365 \text{ days}} \qquad \text{(eqn. 2.9)}$$

Failure Rate (FR), measured in failures per day, can now be utilized in calculating system availability. Substituting FR into equation 2.5 one has:

$$A_o = \frac{1}{1 + FR*(MTTR + MSRT)} \qquad \text{(eqn. 2.10)}$$

BRF is calculated on an annual replacement basis which implies it is based upon a specified operating tempo. Higher or lower operating tempos will likely affect A_o. In version 2.0 of ACIM there is a user defined Operating Level (OL) for each system to try to account for various operating tempos. OL is a dimensionless quantity and defaults to 1.0 if the user does not define it. Augmenting equation 2.10 by use of OL we have:

$$A_o = \frac{1}{1 + OL*FR*(MTTR + MSRT)} \qquad \text{(eqn. 2.11)}$$

If MSRT is allowed to go to zero in equation 2.11, the equation programmed into ACIM for the maximum operational availability of a single system for a single site is:

$$A_o \max = \frac{1}{1 + OL*FR*MTTR} \qquad \text{(eqn. 2.12)}$$

The above derivation terminating in equation 2.12 is only one of many calculations performed by ACIM; but, as will be seen later, its behavior is of importance.

3. Effects of Assumptions upon the A_o Calculation

The assumptions needed to implement this model do have an effect on the availability calulation and thus affect the systems and circumstances to which ACIM is applicable. A general synopsis of the impact of the assumptions upon availability is given below.

The multi-indentured equipment network assumed by ACIM generally poses little difficulty; however, the user must be aware of the implication of this top-down breakdown approach. Namely, if the same item appears in different locations in the structure, each component is treated as a unique item in the operation of the model [Ref. 5]. That is, it is possible for the exact same item to be located on several indenture levels of the same system. For example, in Figure 2.1 an identical item may be designated both SRA-12 and subSRA-231 due to the nature of the equipment configuration.

The effect of the assumption of a multi-echelon support system can be important. If one refers to Figure 2.2 and supposes that PIMA West Coast has five of a particular component in stock and PIMA West Pacific has a demand for this component but has none in stock, ACIM will not allow PIMA West Pacific to be resupplied by PIMA West Coast. Resupply must come from a higher support echelon. This tends to understate availability by creating a situation in which MSRT is generally overstated.[8]

The one-for-one ordering policy precludes consideration of economies of scale for resupply. In reality the supply system managers must address things such as Economic Order Quantity and bottlenecks in the supply processing cycle. The effect of this one-for-one ordering policy

----

[8]How to accurately represent multi-echelon support systems is a very complex topic and is not addressed here.

assumption tends to understate MSRT and thereby overstate availability.

The inability to generate demands whenever one or more systems are down tends to over-estimate availability by reducing the opportunity time for a failure. The greater the number of systems operating, the more difficult this assumption is to reconcile.

The fact that ACIM considers equipment usage at only the lowest echelon reflects a limitation in use of ACIM to systems that at least approximately conform to this restriction.

In defining availability as ACIM does, one must assume the operating tempo of each system is A_o percent of that given in the input data. This means that if a system is supposed to operate at 100 hours per month and availability is measured at 50 percent then one tacitly assumes the system operates at only 50 hours per month [Ref. 6]. The reason that this happens is because the demands provided by the input data through the BRF's are themselves based upon a specific operating tempo. In this example, if one spared the system for 50 percent availability this would be approximately the same thing as sparing on the basis of 50 percent of planned operating tempo. A user aware of this situation can utilize the OL variable that is mentioned in Section II.C.2. However, use of the OL variable at other than its default value of 1.0 automatically makes a further assumption; that is, each component's BRF is similarly and linearly affected by a change in operating level. Since parts are spared at a rate proportional to OL the original problem of sparing to 50 percent of the operating tempo has not disappeared.

D. INPUT DATA

There are two general classes of data which are defined as inputs to the Availability Centered Inventory Model--system-related data and item-related data. The system-related data is a file with records in different formats which give policy parameters, default values, model options, and definitions of sites involved in the operation/support of the equipment. The item-related data gives a variety of factors that define and describe individual parts within the equipment. A basic set of item data is given in one file, with additional item data being given (optionally) in a second file. The various input files and included record formats are identified as follows:

System Data File:

- Format A - Options and Default Values
- Format FA- COSAL Policy Parameters
- Format FB- .42 Provisioning Parameters
- Format FC- UICP Wholesale Policy Parameters
- Format L - Site Data

Item Data File:

- Format I - Basic Item Factors

Additional Item Data File (Optional):

- Format J - MSRT Parameters and Specified Levels

For a few data elements, default values are automatically inserted by the model if not given in the input data. The following format descriptions are very general; the specifics for the format files are contained in Appendix A.

1. System Data File

The system data file contains five different formats as illustrated above. The formats are identified by an alphabetic letter in the first column of each record. All of the records are eighty columns long. They are arranged

in sequence according to the format identification in the first column.

a. Format A - Options and Default Values.

The user, via what is commonly refered to as the "A-card", must choose the following options for the system: the type of optimization mode[9], comparison policy, Mission Essentiality Code (MEC), and default MSRT. Other information placed on the A-card is equipment MTTR, investment target, availability target, response times, Depot Procurement Lead Time (DPLT), depot repair cycle, and scrap rate.

As will be described later, one of the outputs from ACIM is a Cost-Effectiveness Report. The control input parameter for this report is provided on the A-card. By the user's choice, the lines of the report are commanded to be printed by either a specified change in the total number of items stocked or, by a specified change in the availability, or lastly, due to a specified increase in the dollar investment.

b. Format FA - COSAL Policy Parameters

There is only one record in the "FA" format; it provides needed factors for operation of the MCO and FLSIP COSAL policies. The data elements on this record include format identification, type of data, MCO formula parameters, MCO risk floors, MCO risk ceilings, FLISP parameters and CNA policy parameters.

----

[9]The three optimization modes, pure optimization, enhanced optimization, or fixed comparison policy are defined in Appendix A, and II.E.2.

c. Format FB - .42 Provisioning Parameters

There is only one record in the "FB" format; it provides needed factors for operation of the Department of Defense Instruction 4140.42 provisioning policy. The data elements include type of data, range, depth, shortage and holding cost, spot buy rate, low, high and breakpoint procurement costs, non-stocked procurement cost and zero demand probabilities.

d. Format FC - UICP Wholesale Policy Parameters

There is only one record for the "FC" format; it provides needed factors for operation of the Uniform Inventory Control Point (UICP) wholesale policy. The data elements include type of data, obsolescence factor, manufacturing setup cost, shortage cost, holding cost, stocked procurement costs (high, low, and breakpoint), and non-stocked procurement cost.

e. Format L - Site Data

There is one record in the "L" format for each different kind of user or higher level maintenance/supply activity in the support system for the equipment. The model is limited to ten such activities; thus, the number of Format L records must be ten or less. The elements of this card seek to define relevant components of a particular site by using the following data elements: site name, indenture level, echelon, stockage facility, repair facility, lead time, repair cycle, number of locations, number of equipments, comparison policy, ACIR policy, operating level and the levels output format to be utilized.

2. Item Data File

The item data file contains one record for each item of the equipment to be included in the operation of the model. Even though data corresponds to values of an Override Code given as one of the data elements: the length of records in this file must be at least eighty columns (the record may be longer if reference data not needed by the model is entered after column eighty). Whenever a data element conforms exactly to one contained in the Supply Maintenance Program Standard Data Element Dictionary, NAVSUP Publication 508, (commonly referred to as the DEN Dictionary), then the DEN Dictionary reference will be cited. Brief descriptions of the data elements are included in Appendix A. Data elements included in the Item Data file format are: reference number, indenture level, part number (DEN D046D/C002B), nomenclature (DEN C004), cognizance code (DEN C003), number per next higher assembly (DEN D011), unit cost (DEN B503), SM&R codes (DENS D012/D013/D013C), BRF (DEN F027), MRU (DEN C007), MEC (DEN C008E), override code (DEN C007B), overide amount (DEN C007A), and if desired additional references may be added after column eighty.

3. Additional Item Data File

The additional item data file, or J-card file, was modified by Henry Watras when ACIM, version 2.0, was implemented at NPS. The use of the J-cards is a user option. Rather than relying on default values, each item may include additional information: user-MSRT, procurement lead time, depot repair cycle, scrap rate, annual wholesale demand, and stock levels for up to ten specific sites.

E. MODEL DESCRIPTION

Figure 2.4 presents an overview of the ACIM. As described above, input data consists of two main classes, system-related and item-related. These data enable the

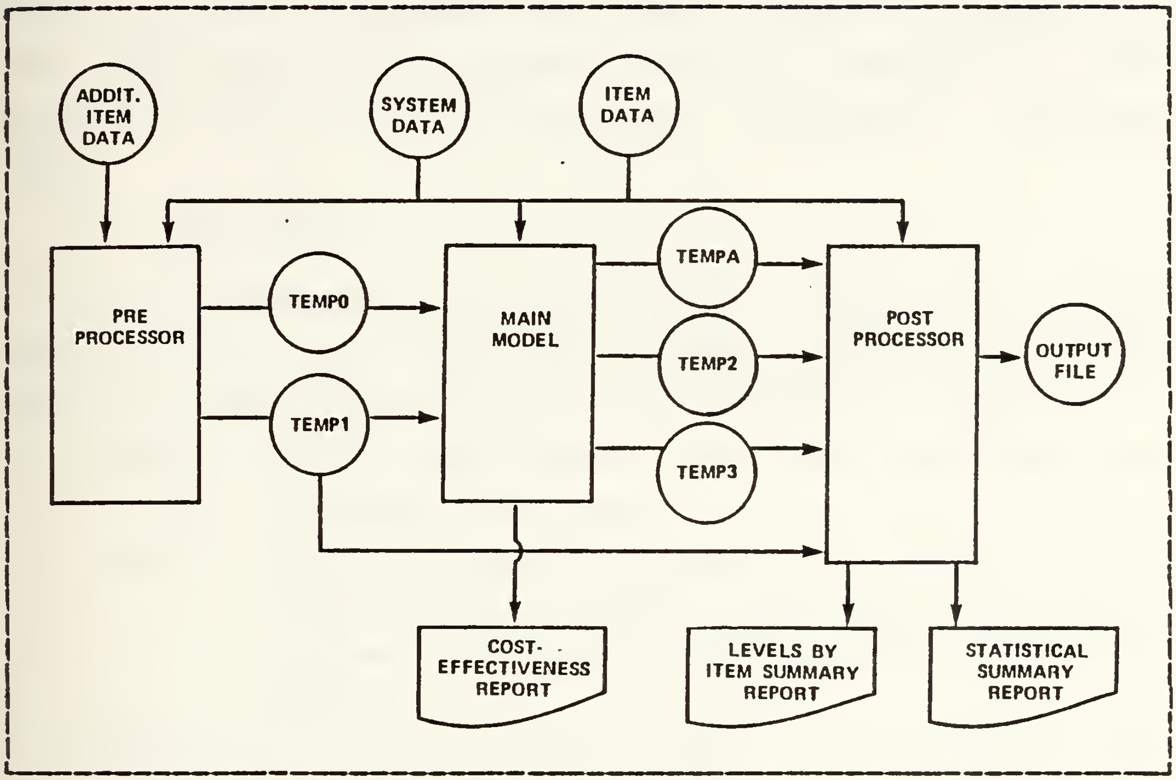

Figure 2.4 ACIM Structure.

three seperate programs (PRE, MAIN and POST processors) of the model tc be operated.

1. Preprocessor

The first program (Preprocessor) has four main functions. First, it reads the input data and determines the number of items and included assemblies and included user sites. Once this is accomplished, the values of the four parameters Mean Supply Response Time (MSRT), procurement

lead time, depot repair cycle and scrap rate are established. Second, stockage levels are computed (or read in from input data) for the designated comparison policy. Third, each item is married with assigned parameter values using either the item data file or system default factors. Finally, if only Consolidated Ship Allowances (COSAL) are being computed, then MSRT for user sites are assigned from the item data file or default factors. Results of these steps are written to the temporary data sets, TEMPO and TEMP1.

2. Main Model

The second program (Main Model) calculates stockage levels in accordance with ACIR. The calculation is iterative in nature and follows the following basic approach:

Step 1: Assume that stock levels for all items and locations are given.

Step 2: Find the item and location for which a stock level increase of one unit will provide the largest increase in system availability per dollar.

Step 3: Increase the stock level of the selected item and location by one unit.

Step 4: Go to step 2 unless the availability goal or budget constraint is reached.

When ACIM is run in the pure optimization mode, the process starts with zero stock levels for all items and locations. However, for other types of optimizations the levels for some or all items and locations are given at the start of the above listed stepwise procedure. At the completion of this algorithm the stockage levels represent the results of using the ACIR. At the option of the user, cost effectiveness reports, which are intermediate results of the Main Model, may be obtained. An example of a cost effectiveness report is shown in Figure 2.5.

3. Postprocessor

The third program, the Postprocessor, takes information from the first two programs and produces two output reports and an output data file.

The first report, Levels by Item Summary Report, lists by sequence number all parts utilized at all sites (one report per site) along with a summary for each item. The second report, the Statistical Summary Report, yields overall results for both ACIR and the chosen comparison policy.

The Postprocessor final action is to write to the output data file. This file takes the system input data and appends to each item the number of sites, stock level for the comparison policy and the stock level calculated by ACIR for the given item and site.[10]

4. ACIM Generated Reports

a. Cost Effectiveness Report

An example of a cost effectiveness report produced by ACIM is shown in Figure 2.5. The ITEM column represents the sequence number of the item whose stock level is being increased by one unit. The next two columns are the cost of the item being incremented and the site number being augmented. The column labeled LEVEL shows the new stock level for the given item and site. The Mean Supply Response Time (MSRT) column displays the MSRT for the equipment as a whole after the stock has been incremented; this value will continue to decrease for a given site. The sequence number of the user site causing the increase in stock level is entered in the USER column. The ASUBO of the user site benefiting most from the stock level increase is

---

[10]The output data file is an not utilized in this thesis.

AVAILABILITY CENTERED INVENTORY MODEL (ACIM) VERSION 2.0
COST-EFFECTIVENESS REPORT
SH60B

ITEM	COST	SITE	LEVEL	MSRT	USER	ASUBO	CUMCOST	CODE	CONTROL
436	130	1	1	43.988	1	0.044735	130	A	44.997971
437	203	1	4	38.634	1	0.050612	1230	A	39.363480
40	12200	1	1	18.377	1	0.100616	297960	A	18.669739
117	422	1	1	11.625	1	0.150032	722916	A	11.628740
27	48100	1	1	8.049	1	0.202751	1274184	A	8.283595
230	72414	1	1	5.921	1	0.256401	1885440	A	6.143064
187	17313	1	1	4.717	1	0.301497	2353514	A	4.753745
25	220000	1	1	3.471	1	0.368655	2970138	A	3.902925
170	54723	1	1	2.974	1	0.404547	3252517	A	3.066908
14	247000	1	1	2.303	1	0.465887	3694674	A	2.667823
165	35511	1	1	1.981	1	0.502357	3949394	A	2.024279
293	35901	1	1	1.599	1	0.553974	4362532	A	1.626669
48	110000	1	2	1.257	1	0.610015	4894120	A	1.318398
9	13000	1	4	1.048	1	0.650122	5285976	A	1.054758
438	603000	1	1	0.673	1	0.737172	6129532	A	0.935442
26	210000	1	2	0.586	1	0.760940	6345095	A	0.671117
312	14992	1	3	0.452	1	0.800462	6688481	A	0.457707
14	247000	1	2	0.279	1	0.858264	7309108	A	0.339162
4	84400	1	2	0.162	1	0.902094	8188211	A	0.169861
406	94850	1	2	0.046	1	0.950239	10362389	A	0.049329

Figure 2.5 Cost Effectiveness Report.

reflected in the ASUBO column; this value will continue to increase for a given site. The CUMCOST column shows the cumulative investment for spares in toto up to that point in the iterative solution cycle. The CODE column identifies the criterion which caused the report line to be printed. In this example a code of "A" reflects the fact that an increment of availibility caused the line to be printed. The CONTROL column number is used to verify that the model is operating correctly. If the number doesn't continually decline in value in a given application, then there is some fault in either the model or the data.

b. Levels by Item Summary Report

Figure 2.6 gives a partial listing of a Levels by Item Summary Report. The Levels by Item Summary Report is much more detailed in ACIM, version 2.0, as compared to

SH60B

AVAILABILITY CENTERED INVENTORY MODEL (ACIM) VERSION 2.0
LEVELS BY ITEM SUMMARY REPORT
SITE 1 - DDG

MODE: OPTIMIZATION
COMPARISON POLICY: .95 PROTECTION

ITEM	REFERENCE NUMBER	IND	PART NUMBER & NOMENCLATURE	COG	POP	UNIT COST	SM&R	BRF	MRU	MEC	OVR C	OVR A	O&ST	COMPARISON MSRT	COMPARISON QTY	ACIR MSRT	ACIR QTY
1	0	1	SH60B		1	0.00	100	249.9400	1	0	Y	0	0.00	7.8968	0	0.0460	0
2	38	2	RADIO RCVR AS	1R	1	16800.00	OG	0.8528	1	1		0	45.00	2.2849	1	0.0787	2
3	107	2	ARMAMENT CONT	1R	1	20800.00	OG	0.1458	1	1		0	45.00	45.0000	0	0.4020	1
4	108	2	ARMT SIG DAT	1R	1	84400.00	OG	0.9611	1	1		0	45.00	2.5638	1	0.0993	2
5	109	2	RCVR-XMTR,UHF	1R	2	9370.00	OG	1.3659	1	1		0	45.00	6.7943	1	0.0038	4
6	110	2	CONTROL,UHF R	1R	1	2700.00	OG	1.5642	1	1		0	45.00	4.0731	1	0.0120	3
7	111	2	BASE MOUNTING	1R	2	135.00	OG	0.0537	1	1		0	45.00	45.0000	0	0.0012	2
8	112	2	SPCH,SCRTY EQ	1R	1	5410.00	OG	4.2000	1	1		0	45.00	1.5627	2	0.0016	5
9	113	2	RCVR-XMTR,HF	1R	1	13000.00	OG	5.5629	1	1		0	45.00	2.5332	2	0.0058	5
10	114	2	AMPLIFER-COUP	1R	1	13000.00	OG	5.5629	1	1		0	45.00	2.5332	2	0.0058	5
11	115	2	MOUNT,RCVR-XM	1R	1	2160.00	OG	0.0537	1	1		0	45.00	45.0000	0	0.1487	1
12	116	2	MOUNT, AMP-CO	1R	1	756.00	OG	0.0537	1	1		0	45.00	45.0000	0	0.0004	2
13	117	2	CONTROL,HF RA	1R	1	2700.00	OG	0.5809	1	1		0	45.00	1.5763	1	0.0371	2
14	121	2	CONVERTER-PRO	1R	1	247000.00	OG	2.8571	1	1		0	45.00	7.0714	1	0.7827	2
15	122	2	CONTROL INDIC	1R	1	57500.00	OG	2.2281	1	1		0	45.00	5.6516	1	0.0330	3
16	123	2	RMT SWITCHING	1R	4	10800.00	OG	0.4701	1	1		0	45.00	4.8354	1	0.0203	3
17	124	2	INTERCONN. BO	1R	2	1460.00	OG	0.1960	1	1		0	45.00	45.0000	0	0.0170	2
18	125	2	RELAY ASSY	1R	1	5620.00	OG	0.6742	1	1		0	45.00	1.8194	1	0.0497	2
19	126	2	APX100TRNSPDR	1R	1	16700.00	OG	0.7616	1	1		0	45.00	2.0481	1	0.0631	2
20	127	2	CMPTR,TRANSPN	1R	1	1660.00	OL	1.5273	1	1		0	45.00	3.9828	1	0.0111	3
21	132	2	BLANKER INTFC	1R	1	9810.00	OG	0.8187	1	1		0	45.00	2.1965	1	0.0727	2
22	133	2	PROC,SPCH SEC	1R	1	6580.00	OL	0.8624	1	1		0	45.00	2.3097	1	0.0804	2
23	134	2	REM CNTRL UNT	1R	1	763.00	OL	0.1808	1	1		0	45.00	45.0000	0	0.0035	2
24	135	2	COMM SCTY EQP	1R	1	7320.00	OL	0.3629	1	1		0	45.00	45.0000	0	0.0146	2
25	136	2	STD ABN CMPTR	1R	1	220000.00	OG	3.5146	1	1		0	45.00	1.1392	2	0.1180	3
26	137	2	CONV-MULTIPLE	1R	1	210000.00	OG	3.4711	1	1		0	45.00	1.1140	2	0.1141	3
27	138	2	CONTROL IND (	1R	1	48100.00	OG	1.7143	1	1		0	45.00	4.4374	1	0.3018	2
28	139	2	CONTROL IND (	1R	1	48100.00	OG	1.7143	1	1		0	45.00	4.4374	1	0.3018	2
29	140	2	TAPE CONTROL	1R	1	114000.00	OG	2.1000	1	1		0	45.00	5.3535	1	0.4424	2
30	141	2	TAPE HANDLING	1R	1	18300.00	OG	11.2000	1	1		0	45.00	0.5603	4	0.0037	7
31	142	2	CONTROL MONIT	1R	1	25600.00	OG	0.2543	1	1		0	45.00	45.0000	0	0.6981	1
32	154	2	RDR NAVIGATIO	1R	1	153000.00	OG	1.3884	1	1		0	45.00	3.6407	1	0.2019	2
33	155	2	DISPLACEMENT	1R	2	28500.00	OG	1.6901	1	1		0	45.00	1.0621	2	0.0086	4
34	156	2	ELECTRONIC CT	1R	2	14700.00	OG	2.6837	1	1		0	45.00	2.3850	2	0.0050	5
35	157	2	CMPS SYS CNTR	1R	2	3090.00	OG	0.3745	1	1		0	45.00	2.0152	1	0.0014	3
36	158	2	XMTR RMT CMPS	1R	2	875.00	OG	0.6965	1	1		0	45.00	3.6521	1	0.0002	4
37	159	2	RCVR/TRANSMIT	1R	1	14700.00	OG	1.1009	1	1		0	45.00	2.9203	1	0.1292	2
38	160	2	CONTROL, RCVR	1R	1	1300.00	OG	0.0607	1	1		0	45.00	45.0000	0	0.1677	1
39	161	2	SHCHMNT,BASE	1R	1	950.00	OG	0.0537	1	1		0	45.00	45.0000	0	0.1487	1
40	162	2	RCVR/TRANSMIT	1R	1	12200.00	OG	2.2047	1	1		0	45.00	5.5974	1	0.0320	3
41	163	2	INDICATOR,HEI	1R	2	4140.00	OD	1.6216	1	1		0	45.00	0.9857	2	0.0073	4

Figure 2.6 Levels by Item Summary Report.

earlier versions, and some of the columns need amplification. Column IND represents the indenture level of the item within a system. CCG column displays a two position code prefixed to Federal Stock Numbers to identify and designate the organization which exercises supply management of the item. In Figure 2.6, a COG of 1R desiginates Naval Air Systems Command (NAVAIR). POP indicates the population of that item on the system. The Military Essentialty Code (MEC) column represents the relative military importance of an assembly in relation to a higher component, equipment or mission as outlined in OPNAVINST 4423.27. The OVR columns present the override code used for each item under both the comparison and the ACIR stockage policies. Appendix A contains further explanations of specific override codes. Finally, Order and Ship Time (O&ST) column refers to the effective O&ST for the item at user-level sites. This is the same as MSRT for the item if one assumes a zero stock level at the user site.

c. Statistical Summary Report

The last report, the Statistical Summary Report, is designed to show the overall results of the model in terms of stockage cost and performance. The first group of statistics shown in Figure 2.7 give an accounting of items in the system in terms of total number and numbers excluded from stockage at the given site for various reasons.

The second group of statistics give an accounting of all stockage candidates in terms of the number of different items stocked and the percentage of candidates that are stocked.

The third group of statistics specifies the investment (in thousands of dollars) for stocked items and is calculated by multiplying the item unit cost times its associated stock level and then summing the resulting products. The non-stocked investment is calculated as the

```
        AVAILABILITY CENTERED INVENTORY MODEL (ACIM) VERSION 2.0
                       STATISTICAL SUMMARY REPORT

SH60B                    SITE  1 - DDG

MODE:  OPTIMIZATION
COMPARISON POLICY:     .95 PROTECTION

                                         COMPARISON POLICY       ACIR POLICY

TOTAL NUMBER OF ITEMS                        441                    441
   # DELETED BY OVERRIDE CODE X                0                      0
   # EXCLUDED BY OVERRIDE CODE Y               1                      1
   # EXCLUDED BY SM&R CODES                    0                      0

NUMBER OF STOCKAGE CANDIDATES                440                    440
   # ITEMS STOCKED                           135                    439
   # ITEMS NON-STOCKED                       305                      1
   PERCENT STOCKED                            30.69                  99.70
   # UNITS STOCKED                           165                    872

INVESTMENT ($000)
   STOCKED                                  4201.733              10362.583
   NON-STOCKED                              1954.240                223.885

PERFORMANCE
   FILL RATE                                   0.747                  0.995
   EXPECTED UNITS-SHORT                       31.511                  1.335
   BACKORDER-DAYS                           1666.733                 32.965
   OPERATIONAL AVAILABILITY
      ACHIEVED                                 0.20583                0.95024
      MAXIMUM ATTAINABLE                       0.97082                0.97082
```

Figure 2.7 Statistical Summary Report.

unit cost times MRU (Minimun Replaceable Unit) summed over all stockage candidates with a zero stockage level.

The last set of statistics give several performance measures for the inventory as a whole. Operational availability statistics are provided for the user and are calculated by both ACIR and a comparison policy.

III. PACK-UP KITS, ACIM AND THE LAMPS MK III

The concept of Pack-Up Kit (PUK) will now be developed by examining the specific PUK for the LAMPS MK III. The specific scope and make-up of a PUK is not a universal constant. Generally, a Pack-Up Kit is an aviation-oriented COnsolidated Ships Allowance List (COSAL). The goal of a PUK is to maintain sufficient spare parts in stock to ensure a 90-day self-sufficiency period during which resupply is considered unavailable [Ref. 7]. In the case of the LAMPS MK III, a PUK, positioned on board a host ship, theoretically contains all the spare parts necessary to allow the aircraft to perform its missions at a pre-determined operating level for a 90 day period.

The Availability Centered Inventory Model (ACIM) employs, in the Main-processor program, the Availability Centered Inventory Rule (ACIR). ACIR is used by ACIM when performing the availability calculations. The ACIR selection process can be biased by the presence of bit-and-piece parts or high-usage, low-priced items which are non-essential for mission fulfillment. This means that if the Availability Centered Inventory Rule is to be used to stock for the LAMPS MK III, then an availability-centered inventory list must be developed which is devoid of non-essential parts. The bit-and-piece parts, because of their low cost per item and their essentiality, are assumed to be on hand and are not present in the availability-centered allowance list. Therefore, the LAMPS MK III PUKs examined in this study are not selected from all possible stockage candidates. However, the exclusion of non-essential parts from the ACIR computation model does not imply that no repair parts of this type should be stocked aboard ship. It does

imply that the conventional Fleet Logistic Support Improvement Program (FLSIP) allowance normally provides adequate coverage for this material. [Ref. 8].

The term essential part is logically tied to a specific mission. In turn, the definition of operational availability, A , used in ACIR is tied to mission requirements. For example, a particular radio frequency signal multiplexer may be essential to mission performance for Anti-Submarine Warfare (ASW), but the same multiplexer may be of no value in an Anti-Ship Surveillance and Tracking (ASST) mission. A down-time created by the failure of the above mentioned multiplexer is only relevant for an availability calculation based on an ASW mission mandate. If the user of ACIM establishes an availability-centered allowance list capable of supporting multi-mission criteria, (e.g. both ASW and ASST), the resultant effect on calculations becomes ambiguous. One cause of the ambiguity relates to the model assumption of Poisson arrival of failures. If a failure occurs, then it is assumed that the aircraft experiences a down-time where no more failures may occur. In a multi-mission environment it becomes more likely that this assumption will be violated because the failure of a part may not create down-time may but merely shift the crew to an alternate mission were more parts failures may occur. In order to minimize the uncertain effects of a multi-mission sparing criteria an attempt was made to have the stockage candidates in the availability-centered allowance list be as consistent as possible with the definition of availability. This was accomplished by defining a single, specific, subordinate mission as the basis for the availability calculation of the LAMPS MK III, and then orienting the availability-centered allowance list around this mission definition.

In order to match the availability-centered allowance list in the most straightforward manner with ACIR computational restrictions, a very basic mission became the

basis for defining operational availability. Only those parts necessary to support the aircraft for Mission Capability (MC) were included in the availability-centered allowance listing. For the purposes of this study, MC defines the ability to perform a basic communications relay mission. Although the primary mission of ASW and secondary mission of ASST are not specifically spared in this study, the above definition of operational availability does not limit the aircraft from being Full Mission Capable (FMC) during any or all of its availability period. That is, MC becomes a lower bound case for capability during the periods of operational availability.

Now that the mission to which the operational availability calculation is tied becomes clearer, the task of generating the availability-centered allowance list from which the Pack-Up Kit is chosen must be addressed. The data under analysis were developed according to Availability Centered Inventory Rule Shipboard Allowance Development Procedures Handbook (NAVSEA TL-441-AA-HBK-010). The procedures outlined are in no sense mathematically optimal. They were developed as a compromise between existing real world constraints and mathematical optimization [Ref. 9]. The results yield a relatively small availability-centered allowance list of 440 items. These items are enumerated in Appendix B. This contains a complete listing of the original, or benchmark, item data file. The item data file is also referred to as the I-cards. The I-cards were received from the Center for Naval Analysis. The dollar-valued information is given in 1983 dollars.

The reader should now realize that the term Pack-Up Kit (PUK) has a very specific meaning in the context of this study. The PUK comprises items that are selected from an availability-centered inventory list which is developed according to pre-established procedures but tailored according to user needs.

Only one LAMPS MK III will likely be deployed per designated ship. Therefore, this study is designed to observe PUK sparing as seen by ACIM for a single LAMPS MK III operating on a ship with no repair capability other than organizational-level maintenance. This level of maintenance is equivalent to remove and replace maintenance capability only. The only aircraft stockage sources aboard the ship are considered to be those contained within the PUK, bit-and-piece parts, and FLSIP provided non-essential parts. Therefore, the general environment under which the PUKs for this study are developed is defined as a single-site, single-echelon, single-aircraft problem.

The focus will now shift to developing a framework for studying the effects on LAMPS MK III PUKs that ACIM envisions under various circumstances.

IV. ANALYSIS OF ACIM SPARING OF LAMPS MK III PUKS

A. INTRODUCTION

The three general categories of scenarios examined through ACIM with the availability-centered allowance listing for LAMPS MK III were:

1) Availability-constrained ACIM optimization,
2) Budget-constrained ACIM optimization, and
3) Fixed-stockage performance.

Prior to the beginning of the analysis a method and structure for comparison was developed and is presented below.

B. ESTABLISHING BENCHMARKS FOR COMPARISONS

In studying the sensitivities of the various parameters it is useful to establish a well-defined set of benchmarks for comparison. The orginal CNA I-card data (item data) contained in Appendix B was used in computing benchmarks. But to be meaningful, the benchmark A-card and L-card parameters must also be outlined. Appendix C contains benchmark A-card and L-cards.

Benchmark A-card parameters are:

Run options: All run options were at their default settings.

Equipment MTTR: The mean time to repair an item was provided by CNA at .062 days or 1.488 hours. This repair time is applied equally to all items that fail and there is no model provision to assign higher or lower MTTRs to specific items.

Availability target: If ACIM is utilized in the availibility constrained optimization mode then the CNA provided value of 82.4 percent target availability was used. If budget-constrained optimization was desired 99.9 percent was assigned.

Investment target: If ACIM were used in the availability-constrained optimization mode then this target data field contained all 9's to ensure the availability constraint was active. After one model application, using all benchmark parameters for the constrained availabilty problem, a budget of $5,222,378 was required for the PUK. This figure became the budget constraint for budget-constrained optimization uses of ACIM.

Part number field size: The default value was used.

User-MSRT: Both Navy and DLA user-MSRTs were always the same and the Navy standard, 420 hours [Ref. 10], were entered as 17.5 days for the benchmark. In the single-echelon, single-site application the response time includes administrative and transportation delays and also a delay

attributable to the chance that the higher supply source may be out of stock; therefore, in this study user-MSRT is equivalent to OS&T when a part is not on hand.

Depot Procurement Leadtime (DPLT): This is not a factor in a single-echelon, single-site scenario, but a value of 365 days was input.

Depot Repair Cycle: A value of 83 days was input, but neither DPLT nor depot repair cycle time are used by ACIM in a single-echelon, single-site situation. For the type of PUK-only computation in this study the pertinent supply factor becomes the total amount of time it takes the user site (Organizaticnal Maintenance for an embarked LAMPS MK III detachment) to receive a replacement part; the length of time ACIM uses for this is represented by user-MSRT.

Scrap Rate: The scrap rate is set to a default value of five percent but has no effect since the repair side of the model is essentially deactivated for the purposes of this study.

Benchmark L-card parameters:

Indenture Level: There was only one level, therefore an indenture code of "1" was entered.

Echelon Code: An "O" was inserted to represent organizational maintenance/supply facility.

Stockage facility: An "X" was entered to indicate that the site maintains inventories of spare parts.

Repair facility: The "O" level maintenance is considered to have no repair capability other than remove-and-replace; therefore, no mark is entered to reflect this.

Lead time: This value was not used by ACIM in this study.

Repair Cycle: This value was not used by ACIM in this study.

Number of locations: A default value of one is used.

Number of equipments: A default value of one is used.

Comparison policy: The user defined J-card option was selected. The stockage levels generated by ACIM when one constrains availability to 82.4 percent and uses benchmark parameters were determined. Then, these stockage levels were entered on the Additional Item Data File (J-card) records

for use by the J-card comparison policy. This method is also termed a fixed-stockage comparison policy throughout this paper.

ACIR policy: The "pure optimization" mode was used.

Availability target: The value entered on the A-card was used by default.

Operating factor: The benchmark is the default value of 1.0.

As discussed above, only selected benchmark parameters were varied. In Table I is a summary of A-card and L-card

TABLE I

A-card and L-card Benchmark Parameters

Parameter	Benchmark value	Card location
Availability target	.824/.999	A-card
Investment target	99999999/5,222,387	A-card
user-MSRT	17.5 days	A-card
equipment MTTR	.062 days	A-card
operating level (CL)	1.0	L-card

benchmark parameters that were studied. For availability target and investment target parameters the first benchmark

value for each refers to the value used in an availability constrained optimization and the second refers to the value used in budget-constrained optimization.

Besides studying the effects of varying these benchmark A-card and L-card parameters, the benchmark item data file values of unit cost and BRF were varied. This was accompished by use of a data translation program that would change these I-card values according to user specification.

Before viewing the results of the analysis it is helpful to recall the iterative nature of the solution procedure used by ACIM. When making use of the model in an availability-constrained application one must realize that ACIM achieved operational availability will always be greater than or equal to the value of the ACIM availability constraint.[11] This occurs because at each iteration a unit of stock is added to the PUK, and the increase in equipment availability due to this added unit of stock is a variable, as is the value of equipment availability at each step of the recursion. The result is a perturbation of the achieved operation availability above the availability constraint; the user should be aware of this when making head-to-head comparisons of the parametric changes. For example, Figure 4.1 shows the perturbations experienced in ACIM operational availability achieved by repeated availability-constrained applications of the model under varying values of user-MSRT.

With the benchmarks defined, the study will now proceed withe three analyses: availability-constrained optimizations, budget-constrained optimizations and fixed-stockage performance. These alternatives are examined by allowing one variable at a time to change. The structure of the analysis is the same in each of the following sections. The resultant PUKs are studied in light of how they are affected

---

[11]A converse argument can be constructed for budget-constrained optimizations.

by the following changes:

1) varying unit cost of all items by a specified percentage;

2) varying BRF of all items by a specified percentage;

3) varying the operating level of the embarked LAMPS MK III;

4) varying the user-MSRT parameter by the same amount amount for both Navy cognizant parts and Defense Logistic Agency (DLA) cognizant parts.

5) varying the of the equipment MTTR parameter;

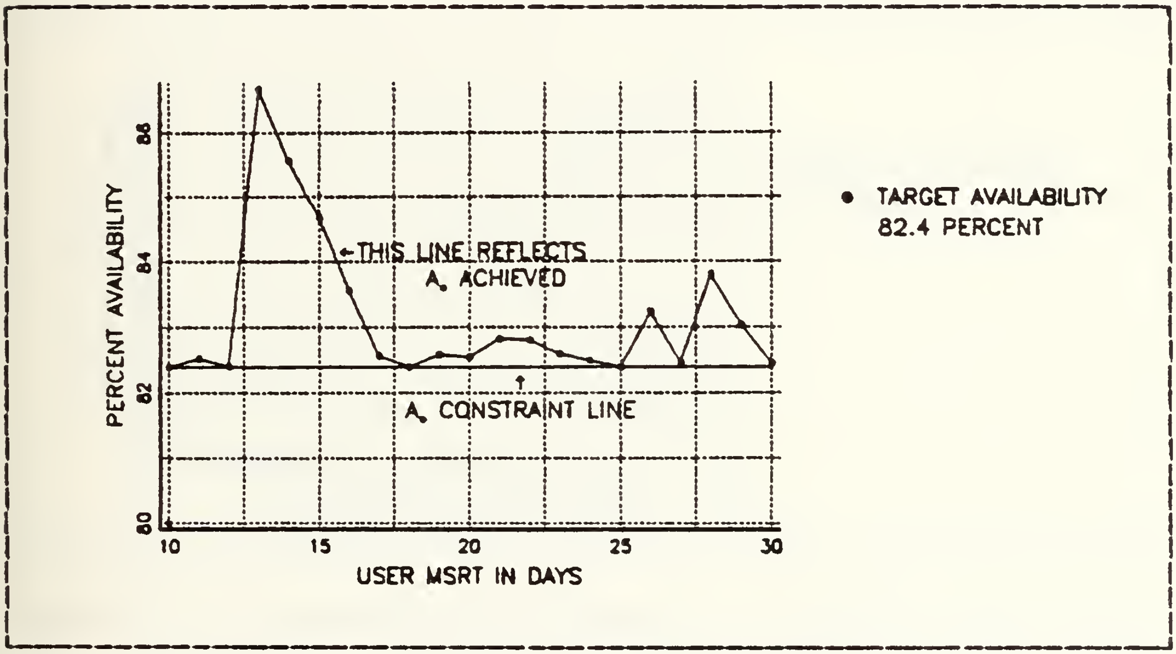

Figure 4.1 A_o Achieved and A_o Constraint: a Comparison.

C. AVAILABILITY-CONSTRAINED OPTIMIZATIONS

This section presents the results of fixing the target operational availability at 82.4 percent and varying key parameters one at a time from benchmark values to observe the effects on the PUK.

1. Effects of Varying Unit Costs

The unit cost is represented in 1983 constant dollars and all comparisons are made in 1983 constant dollars.

In the availability-constrained scenario the effect of the uniformly increasing spares unit cost can be seen in Figure 4.2. The dollar investment in the PUK rises linearly

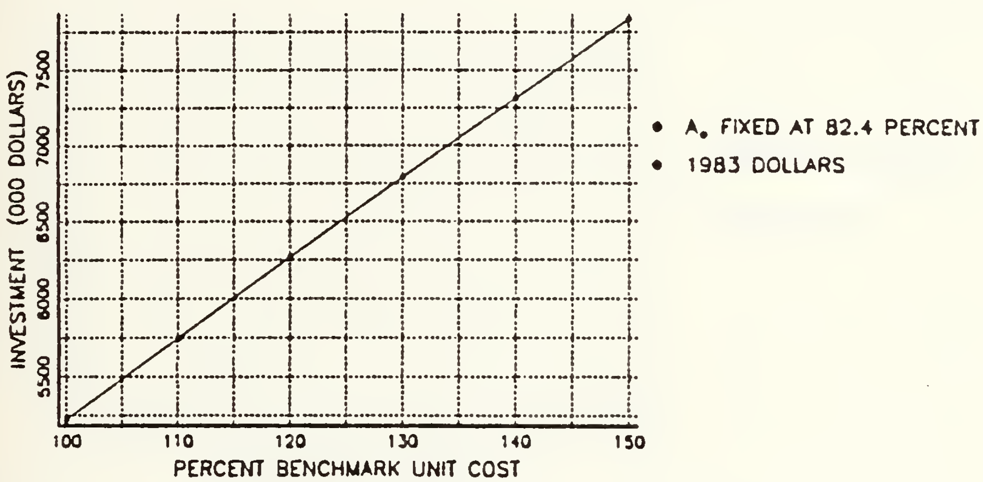

Figure 4.2 Constrained Availability, Variable Unit Costs.

and in direct proportion to a percentage increase in unit cost of all items contained in the availability-centered inventory list. Examination of the Levels By Item Summary Reports confirmed that the stockage of parts is identical in either case. All quantities, except for dollar investment,

in the Statistical Summary Report remain unchanged. This shows that the model optimization procedure in this single-echelon, single-site setting will continue to pick the same inventory items if the percentage change in the cost of items is uniform.

2. Effects of Varying Best Replacement Factor

The Best Replacement Factor (BRF) affected every facet of the Statistical Summary Report. Investment dollars as a function of BRF for this scenario is presented in Figure 4.3. The BRF of all items in the item data file were changed by the same percentage whenever the BRFs were changed. Figure 4.4 shows that the achieved operational availability wanders in a relatively small range above the

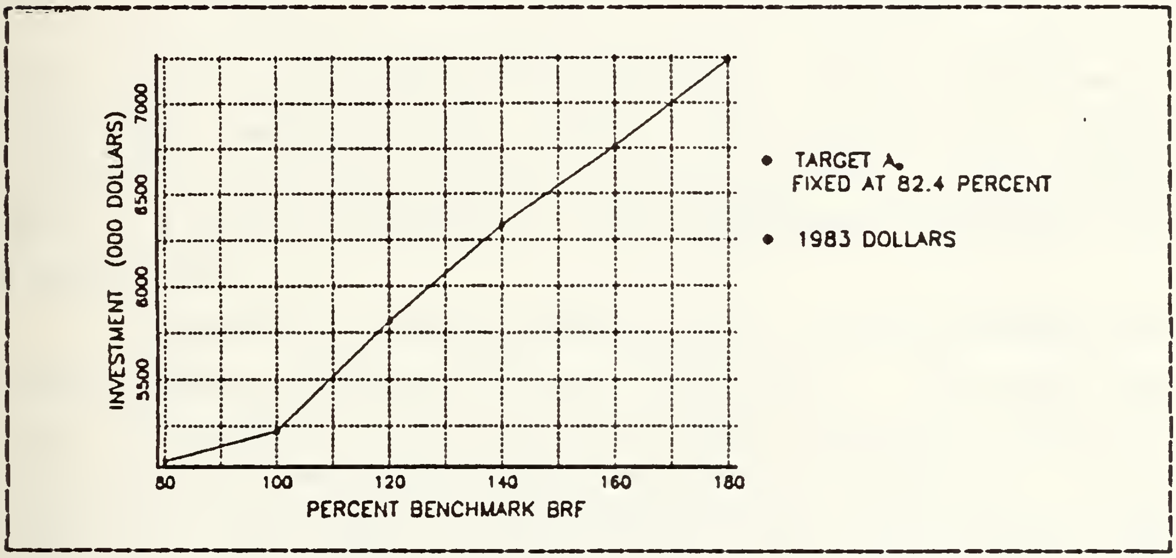

Figure 4.3 Investment as a Function of BRF.

82.4 line, while maximum availability decreases linearly as increasing BRF values are used in equation 2.12. As maximum availability approaches the availability constraint of 82.4, the slope of the investment line in Figure 4.3 should theoretically get steeper. However, in the range of

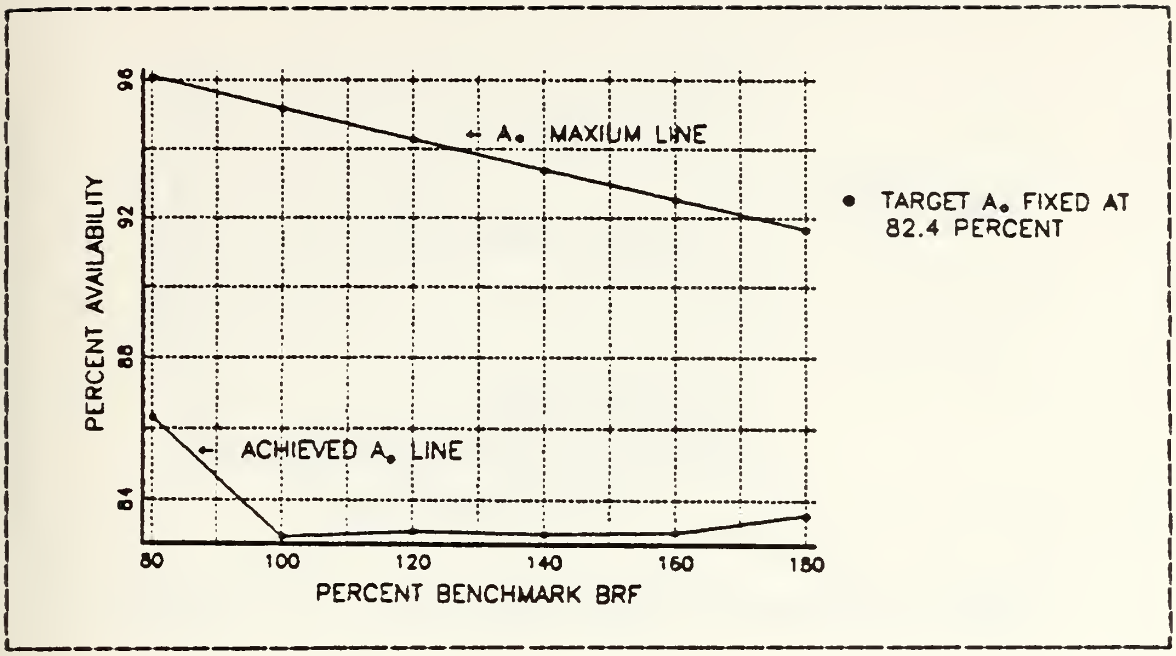

Figure 4.4 Availability as a Function of BRF.

values over which BRF was varied the rate of increase in investment remains quite linear. For every ten percent increase in BRF (if uniform over all items) ACIM expects about a $235,000 increase in the investment requirement for a single PUK.

Figure 4.5 yields insight into how ACIM changes the configuration of the PUK as BRF is varied. The parts that tend to be chosen first because of their desirable effect on availability also tend to be chosen more frequently. It is intuitive that those items deemed most reliable or most expensive will be picked much less often or possibly not all. Therefore, as the benchmark percentage BRF is increased the range or number of types of parts selected increases very little because those parts yet unselected for placement in the PUK do not yield sufficient availability increases per dollar investment.

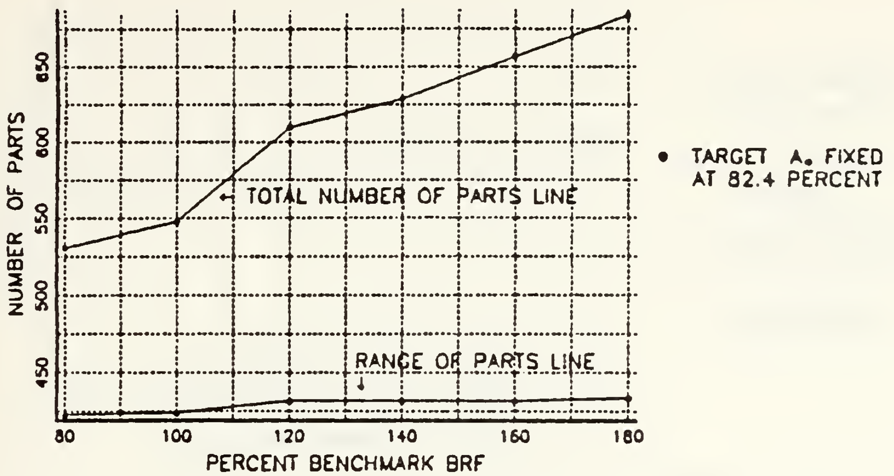

Figure 4.5 Parts Required as Function of BRF.

3. Effects of Varying the Operating Level Parameter

At first, it was assumed that a change in the operating level (OL) parameter would give the same results as those obtained when the BRFs were changed by a similar amount. However, as Figure 4.6 shows, this was not the case. As can be seen in Figure 4.6 the parts that are chosen in each PUK are close with respect to range. The two lower lines shows that the number of different types of parts spared, the range, is virtually the same for either OL or BRF changes. However, one sees that the depth of the spares within the PUKs is more variable when the individual item BRFs are changed. ACIM ranks each item in each iteration in terms of which items yield the largest reduction in MSRT per dollar invested. It can be seen in Figure 4.6 that even though the ranges remained equivalent the total parts levels were more sensitive to BRF changes. The benchmark parameters force intersection of the two total parts curves at the 100 percent point.

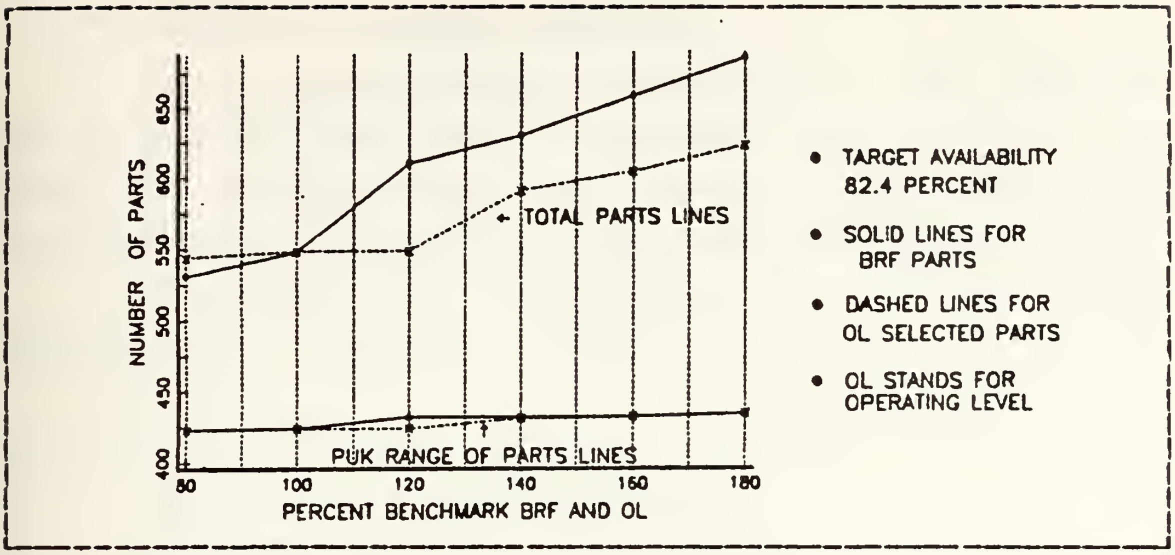

Figure 4.6 Comparison of PUK Parts: OL and BRF Cases.

The result of this disparity in slope between the two total parts lines in Figure 4.6 causes a similar pattern in investment dollars. This can been seen in Figure 4.7.

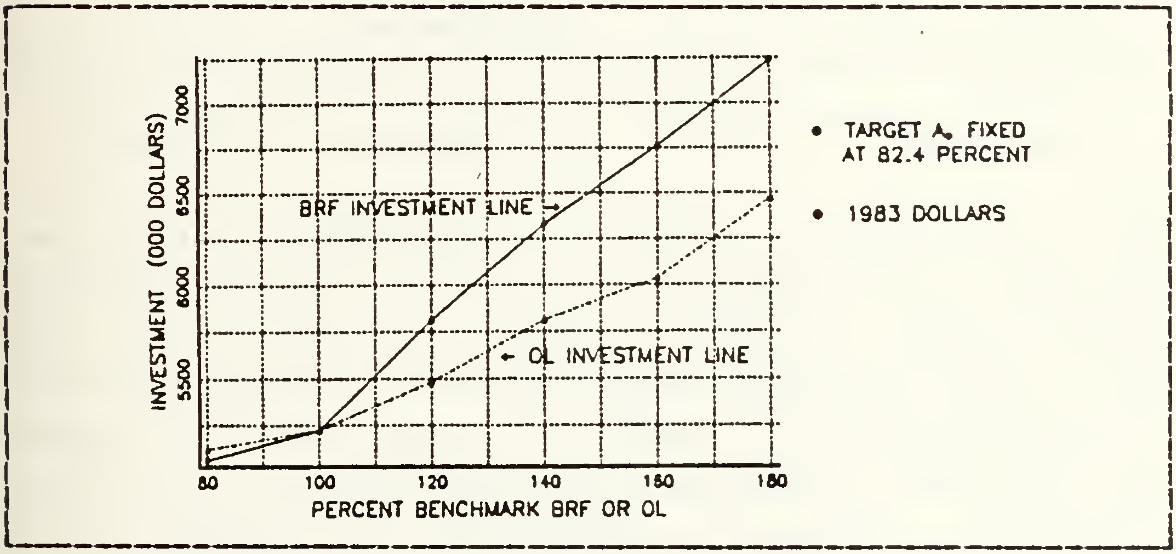

Figure 4.7 Investment as Function of BRF or OL.

4. Effects of Varying User-MSRT

This case was studied extensively. When user-MSRT was changed both Navy and DLA user-MSRT were always of equal value and changed equally even though in the single-site, single-echelon situation only Navy user-MSRT played a role.

In Figure 4.8, investment runs a rather jagged upward trend. Figure 4.9 reveals some of the factors that

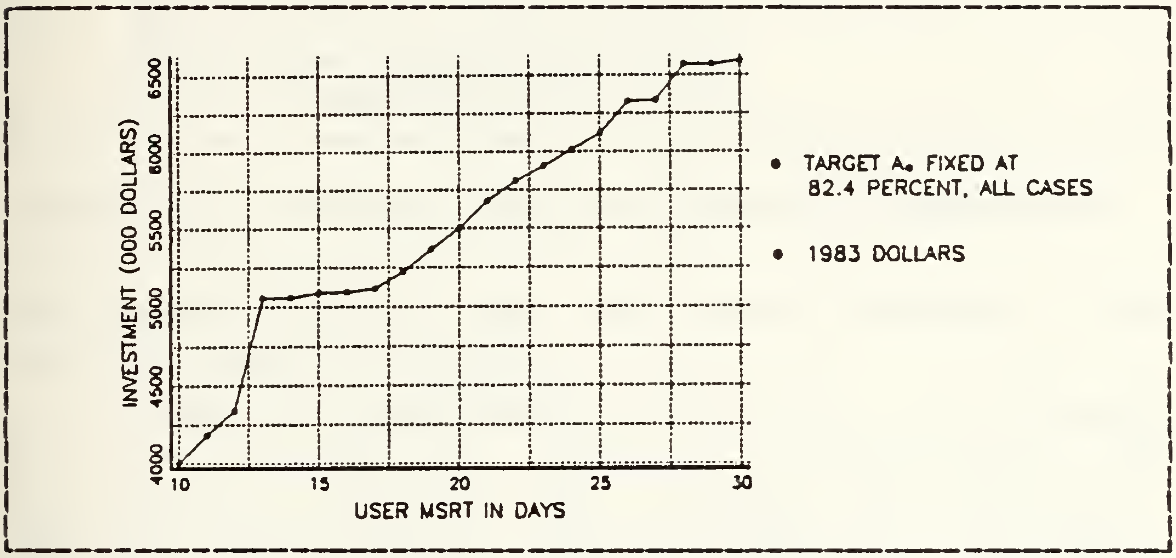

Figure 4.8 Investment as a Function of User-MSRT.

create the relatively flat portions in Figure 4.8. When user-MSRT changes from 12 days to 13 days the most expensive part in the allowance list, a complete engine costing $603,000, becomes attractive for PUK sparing by ACIM. This creates the large spike in achieved availability seen in Figure 4.1, although the target availability remained fixed at 82.4 percent. As one continues to increase user-MSRT, no previously unstocked items are added to the PUK until user-MSRT advances to 18 days. During this period, 13 thru 17 user-MSRT days, the achieved availability spike is whittled down toward the target availability of 82.4 percent by

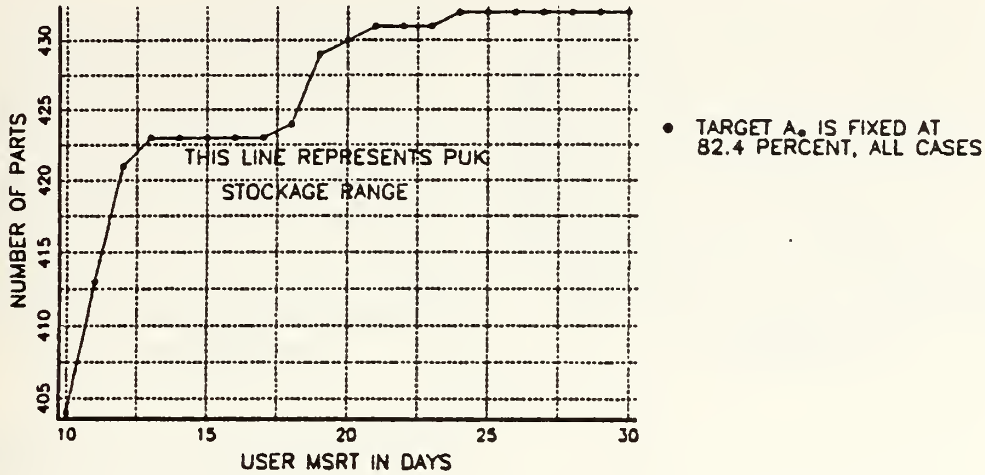

Figure 4.9 Stockage Range as a Function of User-MSRT.

only modestly changing the PUK sparing investment while user-MSRT continues to climb.

There is considerable variability in investment change per user MSRT day. However, a rough rule of thumb for this data base is: for every one day increase in user-MSRT there is about a $130,000 increase in the cost of the PUK in order to maintain the target availability of 82.4 percent.

The performance statistics section of the Statistical Summary Report yield statistics on fill rate, expected units short and backorder days. The performance results obtained in this constrained availability environment are shown in Figure 4.10. The results are surprising in that as the number of user-MSRT days is increased there is a decrease in backorder days, an increase in fill rate and a decrease in expected units short. This is counter-intuitive since it seems that an increase in waiting time for a part should generally cause performance to deteriorate. A more complete analysis of this result is addressed in the budget-constrained, user-MSRT section.

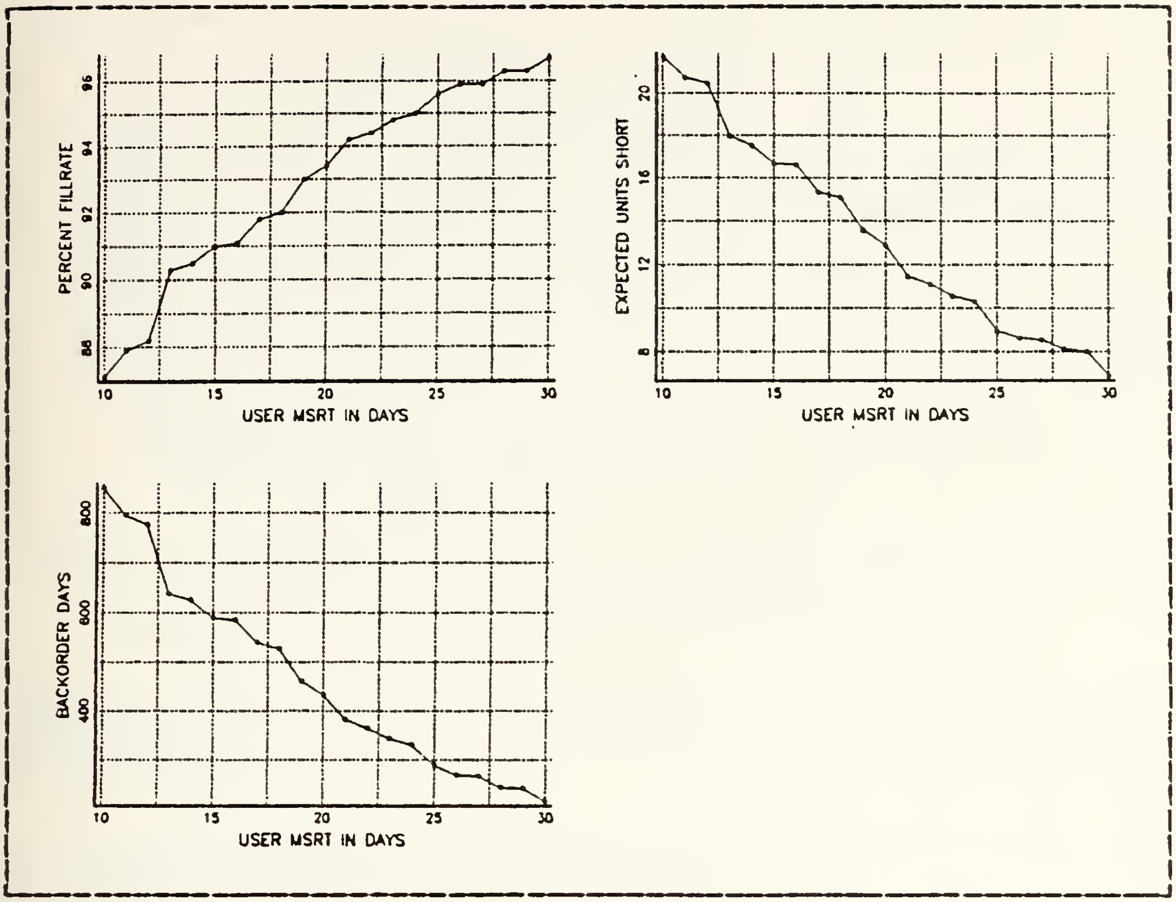

Figure 4.10 Performance Results with Variable User-MSRT.

5. Effects of Varying MTTR

MTTR for a system is a constant for ACIM purposes. The benchmark MTTR was .062 days or 1.488 hours. One can see, in Figure 4.11, that over a fairly wide range of hours per repair the investment in the PUK rises relatively little. This is to be expected because of the low impact MTTR has in the availability formulation used by ACIM.

This does not imply that an increase in MTTR from 1.1 hours to 2.6 hours would not severely hamper the ability of the LAMPS MK III to sustain high tempo operations. Rather it indicates that the ACIM does not weight MTTR heavily in its determination of stockage levels. How much

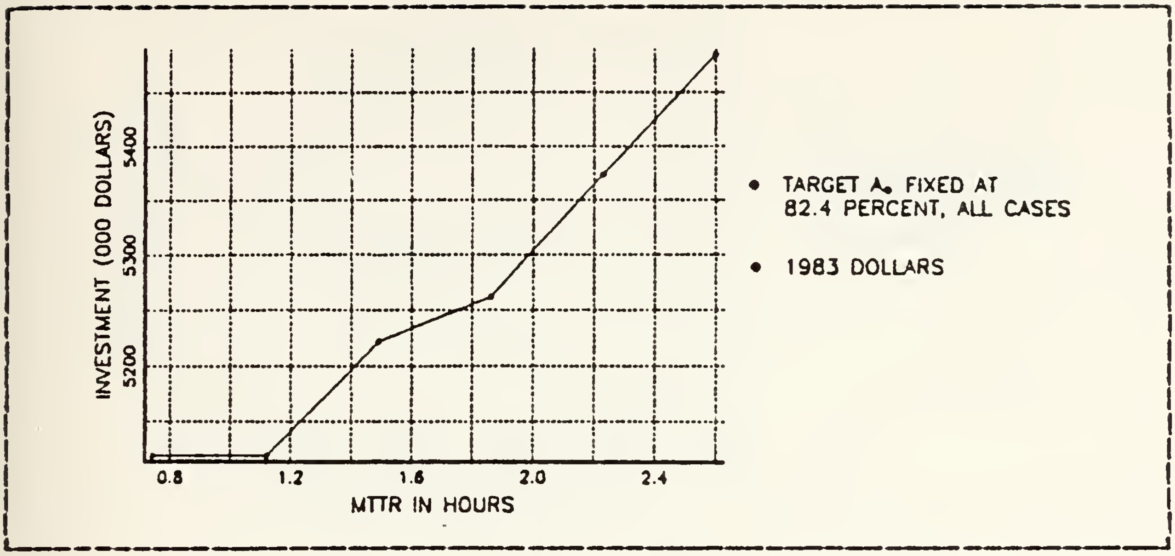

Figure 4.11 Investment as a Function of MTTR.

ACIM underestimates the true effect of an increase in MTTR is not known.

D. BUDGET-CONSTRAINED OPTIMIZATIONS

In this section the budget is fixed at the benchmark value of $5,222,378. The format of the analysis of this section will be the same as in the previous section with regard to order of presentation of results. The emphasis will be on availability and the PUK configuration but the performance statistics from the Statistical Summary Report will also be discussed.

1. Effects of Varying Unit Costs

Via a data translation program each unit cost in the I-card (item) data base was changed an amount designated by the user.

One sees in Figure 4.12 that there is no effect on the variables in the maximum availability calculation because the A_o maximum remains constant at the benchmark

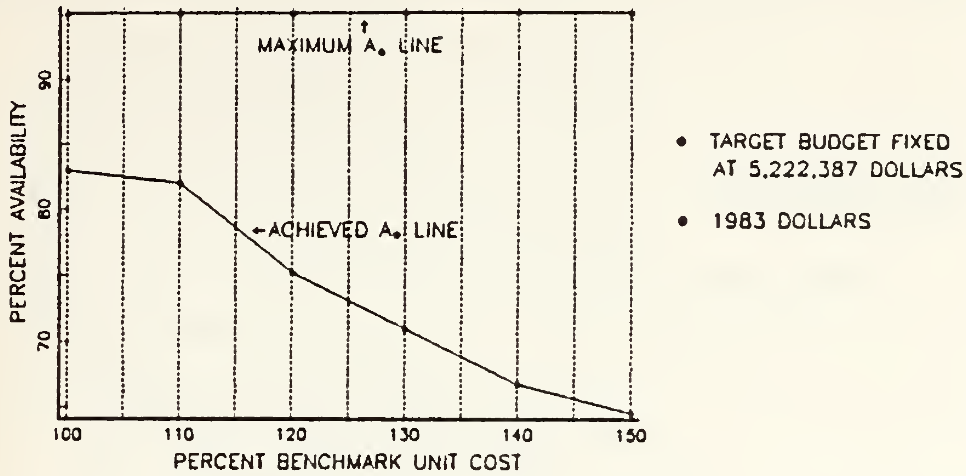

Figure 4.12 Achieved Availability vs. Unit Cost.

value of 95.19 percent. However, the effect on the achieved operational availability due to uniform unit cost increases is devastating. ACIM depicts the reduction in achieved availability as roughly linearly decreasing as unit cost increases. For the LAMPS MK III data used in this study a 10 percent increase in unit cost creates about a 3-4 percent decrease in achieved operational availability.

The lower line in Figure 4.13 shows how the range of the PUK is depleted as unit cost increases. The upper, total parts, line shows how the total number of spares decreases as unit cost is increased.

Increases in backorder days are experienced as unit costs increase. The primary reason for this is that as price is increased the stockage level drops; thus, the greater is the chance that demand will exceed stock on hand thereby driving backorder days upward. This in turn drives the expected number of units short upward and the fill rate down. These results are graphically represented on the three graphs located in Figure 4.14.

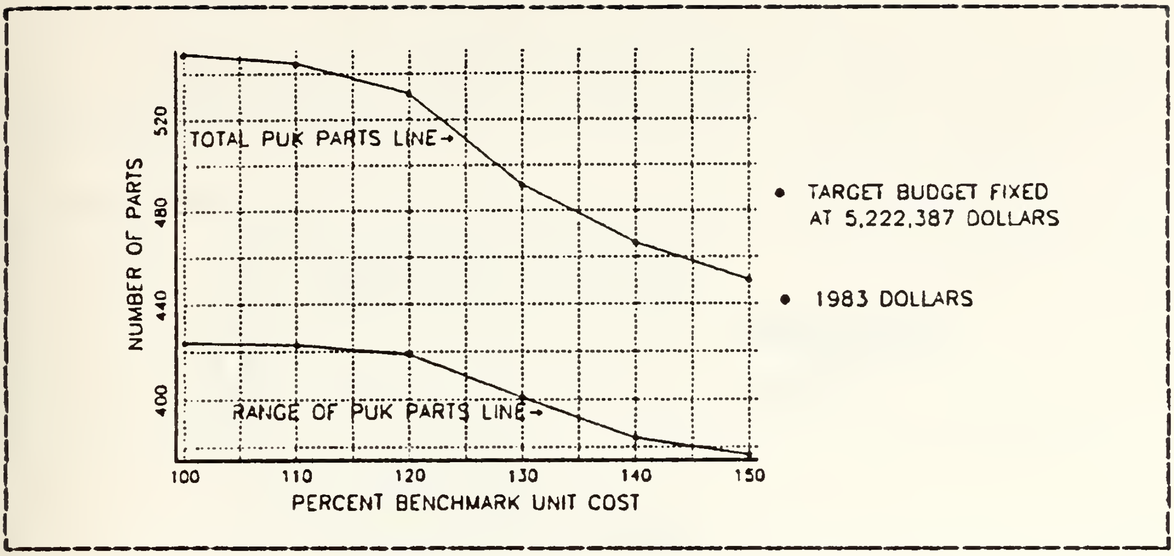

Figure 4.13 Parts Chosen as a Function of Unit Cost.

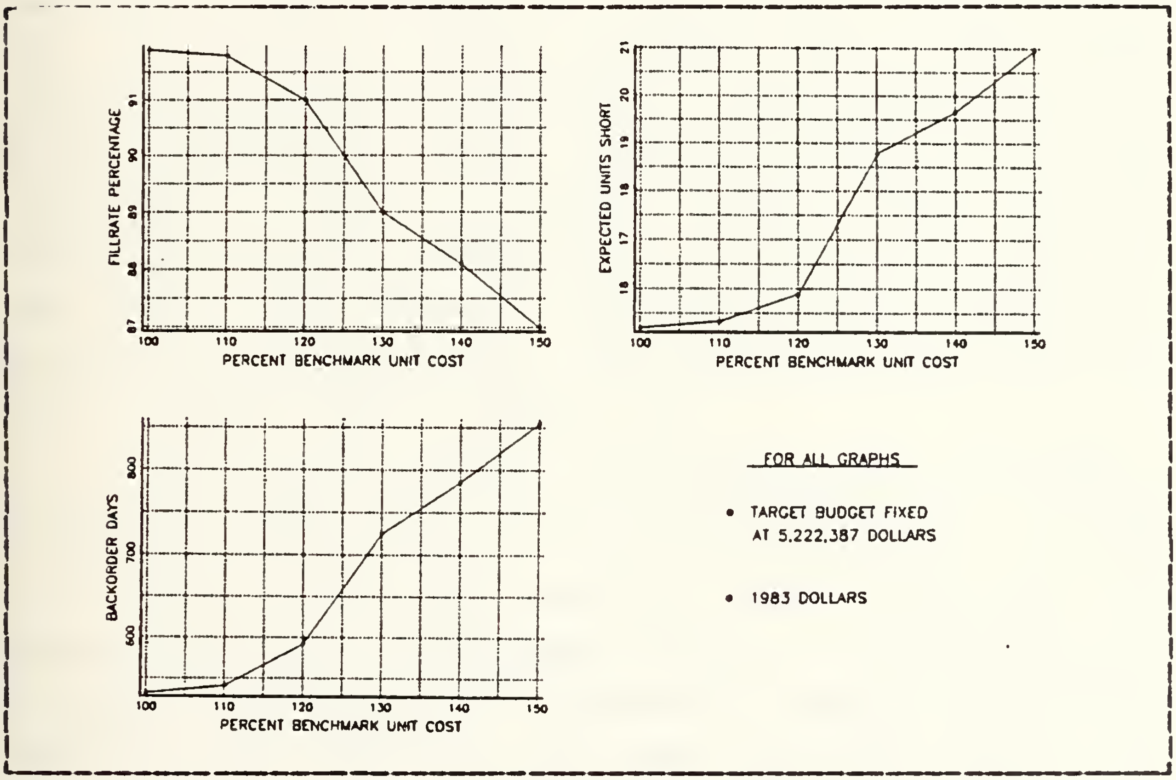

Figure 4.14 Performance Results with Increasing Unit Costs.

2. Effects of Varying BRF

Figure 4.15 depicts the downward trend in maximum availability and achieved availability, as BRF is uniformly

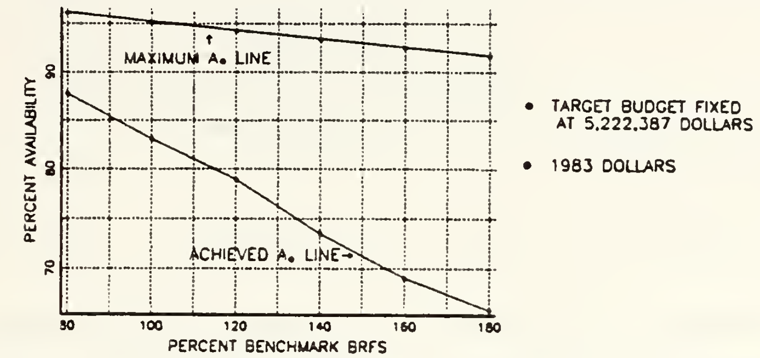

Figure 4.15 Availability vs. Percent BRF.

increased. This is what one would expect. As the failure rate is increased through increased BRFs, the reduced maximum availability is expected. The downward trend in maximum availability places increased pressure on achieved availability. While the budget is kept fixed, achieved availability is also affected by the increase in individual item BRFs. The result is that the achieved availability decreases at a faster rate than the maximum availability. This is clearly seen in Figure 4.15.

Due to the budget constraint, ACIM envisions a slightly decreased range but increases depth in an attempt to optimize availability. This is demonstrated in Figure 4.16. This is the first time this result was seen. The calculations used by ACIM appear logical. As BRFs increase, the usage of all parts is increased. ACIM in turn slowly sacrifices the items with the least marginal return from range while it must increase the depth of some of the remaining parts.

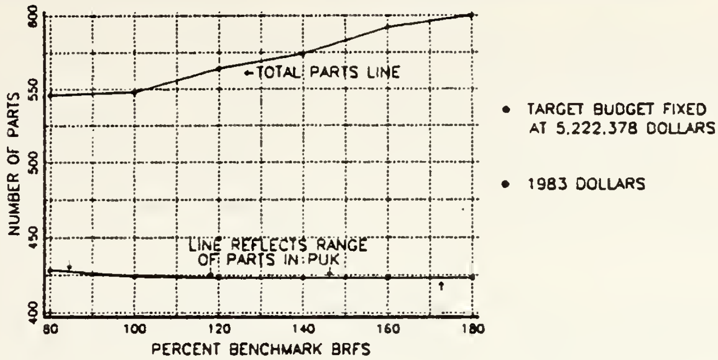

Figure 4.16 Sparing Total Parts and Range vs. BRF.

When BRF increases, the demand for spares increases, and thus backorder days rise as demand rises above supply on hand. This causes an increase in expected units short and a reduction in fill rate. This can be seen in the performance graphs presented in Figure 4.17.

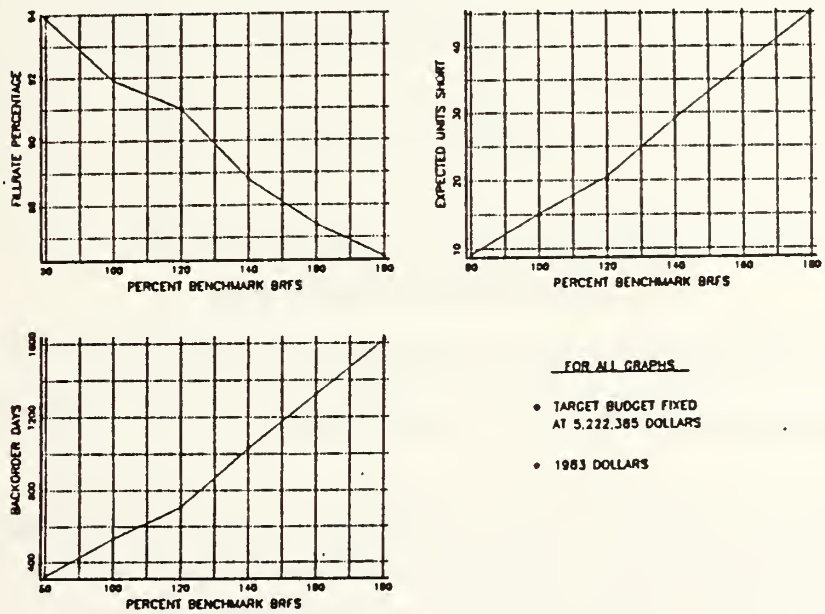

Figure 4.17 Performance Results with Variable BRF.

3. Effects of Varying the Operating Level

This site data parameter called Operating Level (OL) yields availability results similar to those created by a uniform percentage change in BRF across items. There are however, differences between the two approaches in how ACIM spares PUKs.

In Figure 4.18 one observes that the maximum availability obtained when using ACIM and changing the OL is the

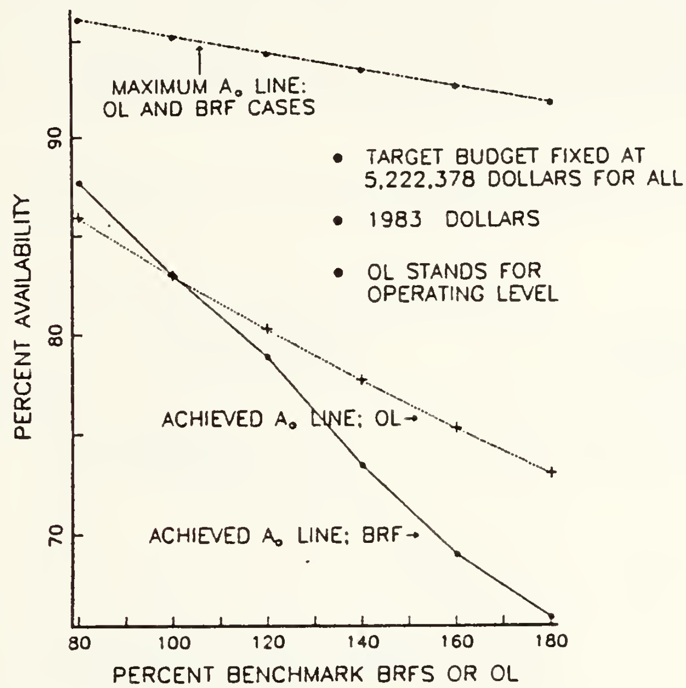

Figure 4.18 Availability vs. Operating Tempo.

exact path followed for maximum availability in Figure 4.15. Figure 4.18 has borrowed the achieved availability line from Figure 4.15 and juxtaposed it with its OL counterpart. Changing the BRF of each item is shown to decrease achieved availability faster than changing the OL paramter.

All other aspects of changing the OL factor yield results which are identical to the benchmark case. That is, changing OL in a budget constrained optimization does not affect range, depth, fill rate, backorder days, or expected units short for the PUK selected.

4. Effects of Varying User-MSRT

The user-MSRT changes provides no startling results; the model appears to operate and stock the PUKs in the manner expected.

Figure 4.19 shows the drop in achieved operational availability as user-MSRT is varied between ten and thirty days. Since the maximum availability calculation assumes an

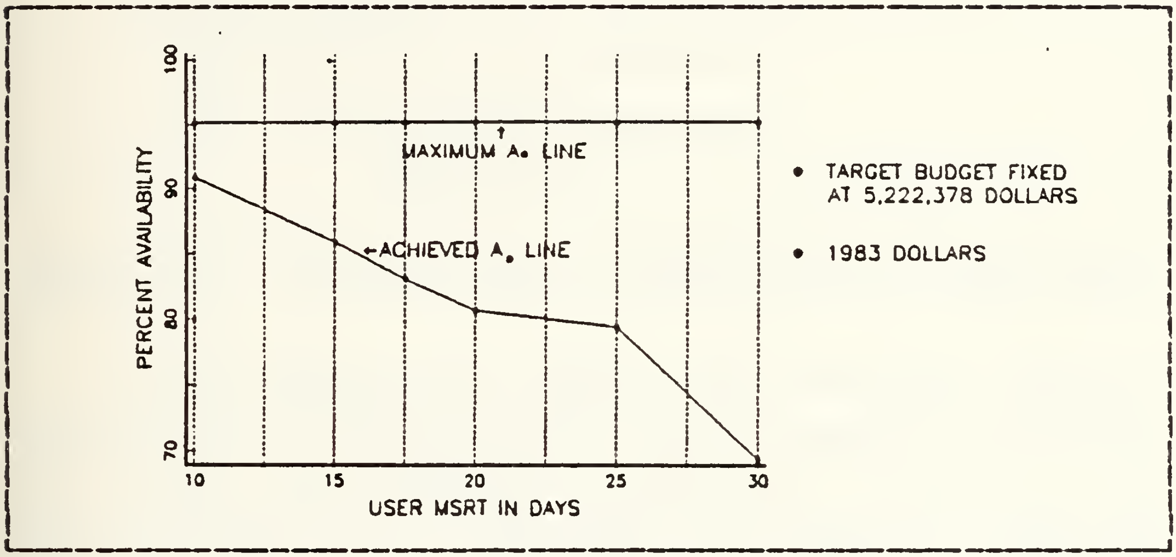

Figure 4.19 Availability vs. MSRT.

MSRT of zero, the maximum availability calculation performed by ACIM is unaffected by changes to MSRT. For the LAMPS MK III availabilty-centered allowance list utilized in this study, ACIM predicts slightly more than a one percent decrease in availability for every one day increase in user-MSRT.

In the case of increasing BRF, ACIM attempts to slowly sacrifice range for increased number of total parts in obtaining its solution. The tradeoffs made by ACIM when faced with increasing user-MSRT are similar to those used when faced with increasing BRF. This is depicted in Figure 4.20.

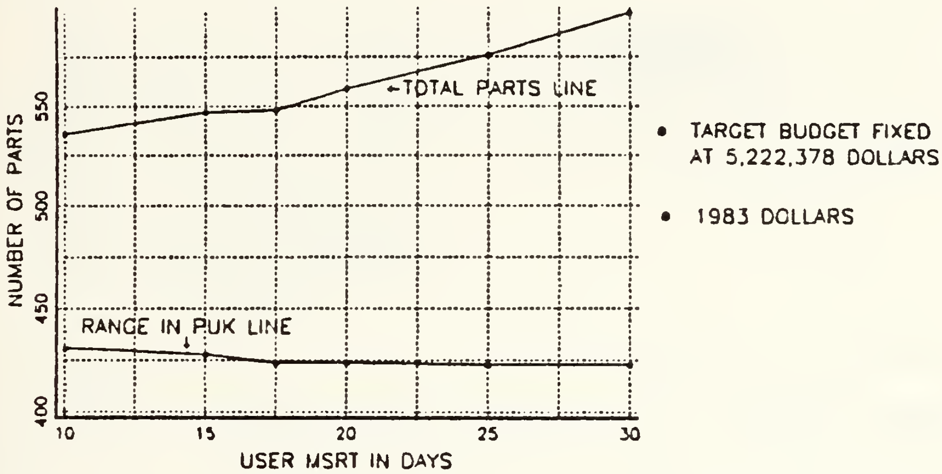

Figure 4.20 Sparing Range and Total Parts vs. user-MSRT.

The performance results with increasing MSRT as compared with increasing BRFs run in opposite directions. This is seen by contrasting the graphs in Figure 4.17 with those in Figure 4.21. The graphs in Figure 4.21 show that ACIM predicts a decrease in the total number of backorder days (and, consequently, an increase in fill rate and a decrease in expected units short) with an increase in user-MSRT. These results are counter to what one would expect to see. One possible explantion for the performance observed in Figure 4.21 is that the increase in user-MSRT results in decreased range and increased depth of the less expensive items. This would possibly result in a reduced number of stockouts.

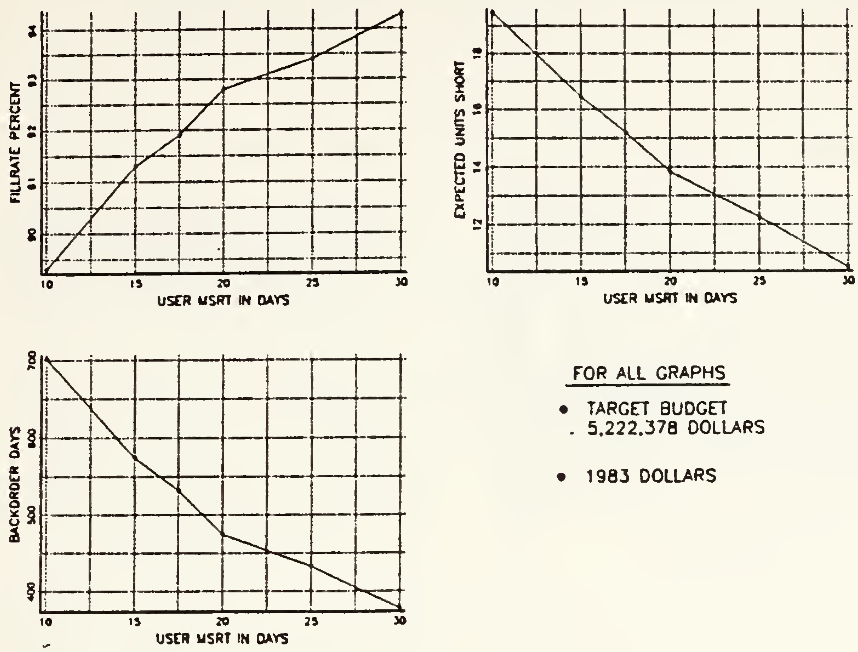

Figure 4.21 Performance Results with Changing MSRT.

In order to be able to determine whether there was a programming problem with ACIM the data translation program used to vary I-card BRF and unit cost data was modified. The data translation program was changed so that each item within the availability-centered allowance list, I-cards, of the LAMPS MK III was given the same BRF of .5 per year and the same cost of 1000 dollars per item. If backorder days[12] continue to decrease with increasing user-MSRT when the data base has been configured in this way, then it is safe to deduce that there is either a problem with the programming used in ACIM or there is a problem with the model theory.

----

[12]The result of the backorder days calculation drives the computation of both fill rate and expected units short. For details see Reference 1.

In Figure 4.22 the graph on the left represents the trend of investment as user-MSRT is increased in a constrained availability environment while using the uniform

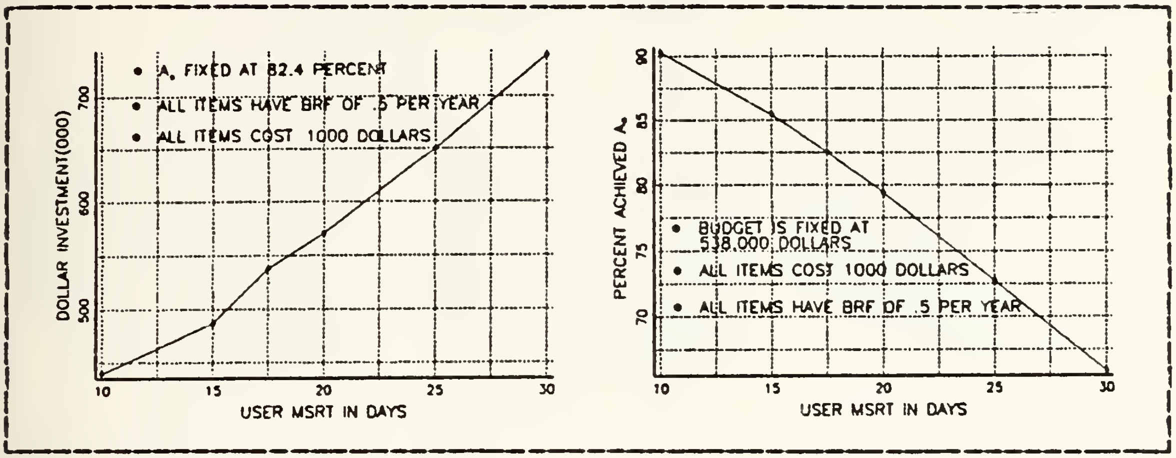

Figure 4.22 Uniform BRF and Unit Cost Results.

BRF and cost data as described above. One sees that the investment increases as user-MSRT increases. This is intuitive and agrees in direction with the results obtained when the user-MSRT was varied using the original item (I-card) data. The graph at the right side of Figure 4.22 portrays the downward trend in availability as user-MSRT is increased using the uniform BRF and cost data base in a budget-constrained environment. This is analogous to the results obtained with the original I-card data.

Thus far in this section it has been shown that the data base with uniform item BRF and unit cost yields results parallelling those of the original data base of I-cards. That is, in all constrained availability scenarios investment rises with increases in user-MSRT, and in all constrained budget scenarios availability decreases with increases in user-MSRT. Now attention is turned to the performance statistics one gets with the data base of

uniform unit cost and item BRF. If the results parallel those of the original data base of I-cards then a problem with ACIM has been found.

Figure 4.23 presents the performance results when the uniform I-card data base is used. The top three graphs

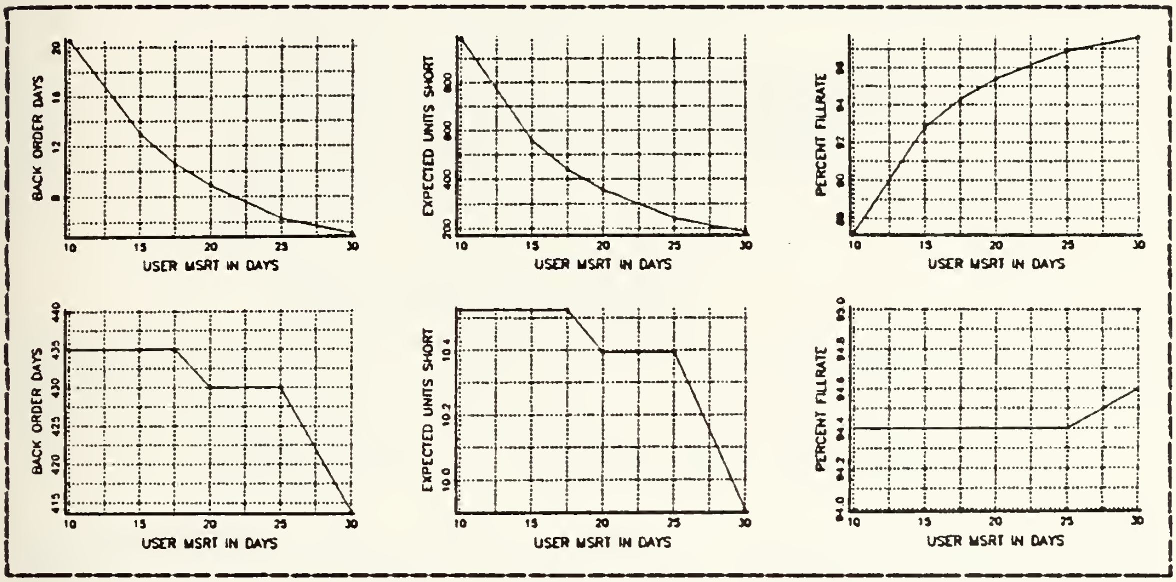

Figure 4.23 Performance Results: Uniform Unit Cost and BRF.

of Figure 4.23 represent the performance results in an availability constrained environment. The bottom three graphs of Figure 4.23 represent the performance results in a budget-constrained environment. Although the magnitudes of the results differ greatly with the original LAMPS MK III data it is easily seen that the trends are all similar. That is, as user-MSRT increases, backorder days decreases, expected units short decreases, and the fill rate increases. Since these results are impossible for the example investigated here, it is clearly the case that some of the performance statistics produced by ACIM are incorrect.

5. Effects of Varying MTTR

The effect of changing MTTR on availability is seen in Figure 4.24. For a fixed budget, changes in MTTR do affect maximum availability and thus affect the percent

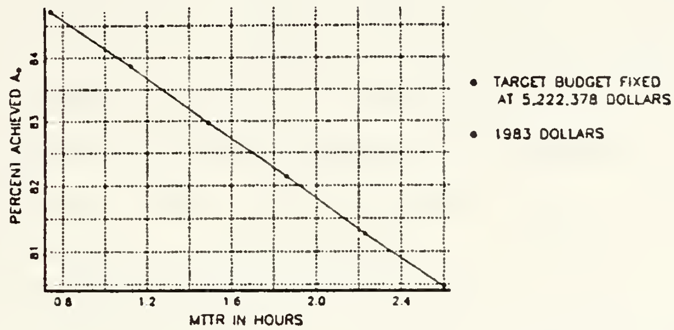

Figure 4.24 Availability vs. MTTR.

achieved opertational availability. However, stockage level computations in this single-echelon, single-site scenario with the LAMPS MK III are not affected by changes MTTR.

E. FIXED-STOCKAGE PERFORMANCE

ACIM, version 2.0, has the ability to use any one of seven comparison policies. The one explored here is a user-defined comparison policy which fixes the stockage levels of the PUK. The author was was interested in determining how ACIM viewed the "optimal" results produced by the Availability Centered Inventory Rule (ACIR) compared with the "sub-optimal" results that must be produced when PUK inventory is held constant and parameters are allowed to vary. For this study it involved taking all benchmark I-card, L-card, and A-card data and parameters and letting ACIM solve for the inventory level in an availability-

constrained optimization. The availability constraint was set at 82.4 percent. The resultant PUK inventory levels were then entered on J-cards. By selecting the user-defined comparison policy, it was possible to freeze the items in inventory at the levels now defined by the J-cards and compare the results with the Availability Centered Inventory Rule (ACIR) sparing. Since the J-card comparison stockage levels were fixed, the only meaningful direct comparisons that could be made with this fixed-stockage policy were with the ACIR results from budget-constrained optimizations. This is because each policy would have the same budget (investment level) and therefore a basis for comparison. Availability-constrained optimizations were not suitable for comparison with the fixed-stockage results because there lacked a common basis for comparison.

When parameters were changed, the fixed-stockage policy could always be purchased with the same level of investment but the resultant achieved operational availability would be lower. When parameters were changed, the ACIR availability-constrained results would always yield about the same achieved operational availability but the investment level would vary. Therefore, the PUKs selected by availability-constrained ACIR optimizations were not comparable with fixed-stockage PUKs because neither availability or investment provided a basis for comparison.

Comparisons between budget-constrained ACIR optimizations and the fixed-stockage PUKs could not be made when unit costs were varied. This is because the fixed-stockage levels always produced the same operational availability but at a different investment level than the buget constraint utilized in the ACIR optimizations. So again, there was no basis for comparison. However, when parameters varied, the investment for the fixed-stockage policy always equalled the investment limit used in the budget-constrained ACIR opti-

mizations; so there was a basis for comparison. Therefore, this section will deal with the budget-constrained optimizations as they compared with fixed-stockage (J-card defined) PUKs as one of the following four parameters was varied: 1) I-card BRFs; 2) L-card operating factor; 3) user-MSRT; and 4) MTTR.

These comparisons attempt to explore what ACIM envisions might happen if the parametric values change over time and one is forced to remain at a predetermined level of stock as compared to reoptimizing the stock levels of the PUK as the parameters change.

1. Effects of Varying BRF

The first comparison made is between the achieved operational availability under the two policies each with the same budget. This is depicted in Figure 4.25. The contention that the ACIR availability is optimal is not violated by these results. In other words, ACIM does indeed show that the fixed-stockage (J-card) achieved availability is at all points less than or equal to the ACIR achieved availability. It is also noted that the reduction in the percent availability achieved by the fixed stockage (J-card) PUKs was exactly 30 percent of the increase in BRF. In the extreme case in Figure 4.25, the BRFs increased by eighty percent over benchmark levels while availability dropped twenty-four percent.

An eighty percent increase in BRF causes a dramatic drop in availability for both ACIR and fixed-stockage (J-card) PUKs. However, what is surprising, is how closely the sub-optimal, fixed-stockage (J-card) policy availability parallels the "optimal", ACIR results. Even at the extreme point of eighty percent increase in benchmark BRFs, there was only a six percent difference in availabilities.

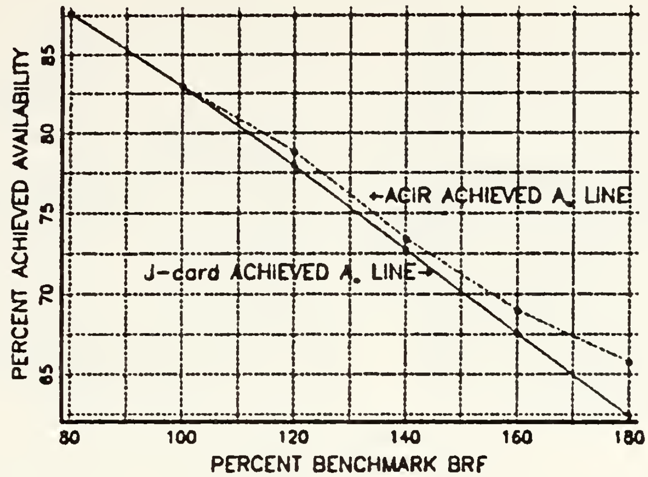

Figure 4.25 A_o Comparisons: Fixed Budgets, Variable BRFs.

The performance statistics of fill rate, expected units short and backorder days were examined next. ACIM computational results in these areas agree with the availability lines. In Figure 4.26 the fill rate lines are depicted. This shows that as BRF is increased fill rate drops less rapidly when the card "optimal" PUK can be picked each time. Since ACIR is allowed to pick a new PUK, its relatively better performance in reduced backorder days, and expected units short was anticipated.

2. Effects of Varying the Operating Level

ACIM does not respond well in this PUK (COSAL only) scenario to changes in the L-card OL variable. The fixed-stockage (J-card) maximum availability line follows exactly the ACIR maximum availability line. This was expected. However, across the entire range of percent BRFs there was consistently only a .03 percent advantage in achieved availability for the ACIR PUK. Fill rate, backorder days and expected units short all remained at exactly the same level

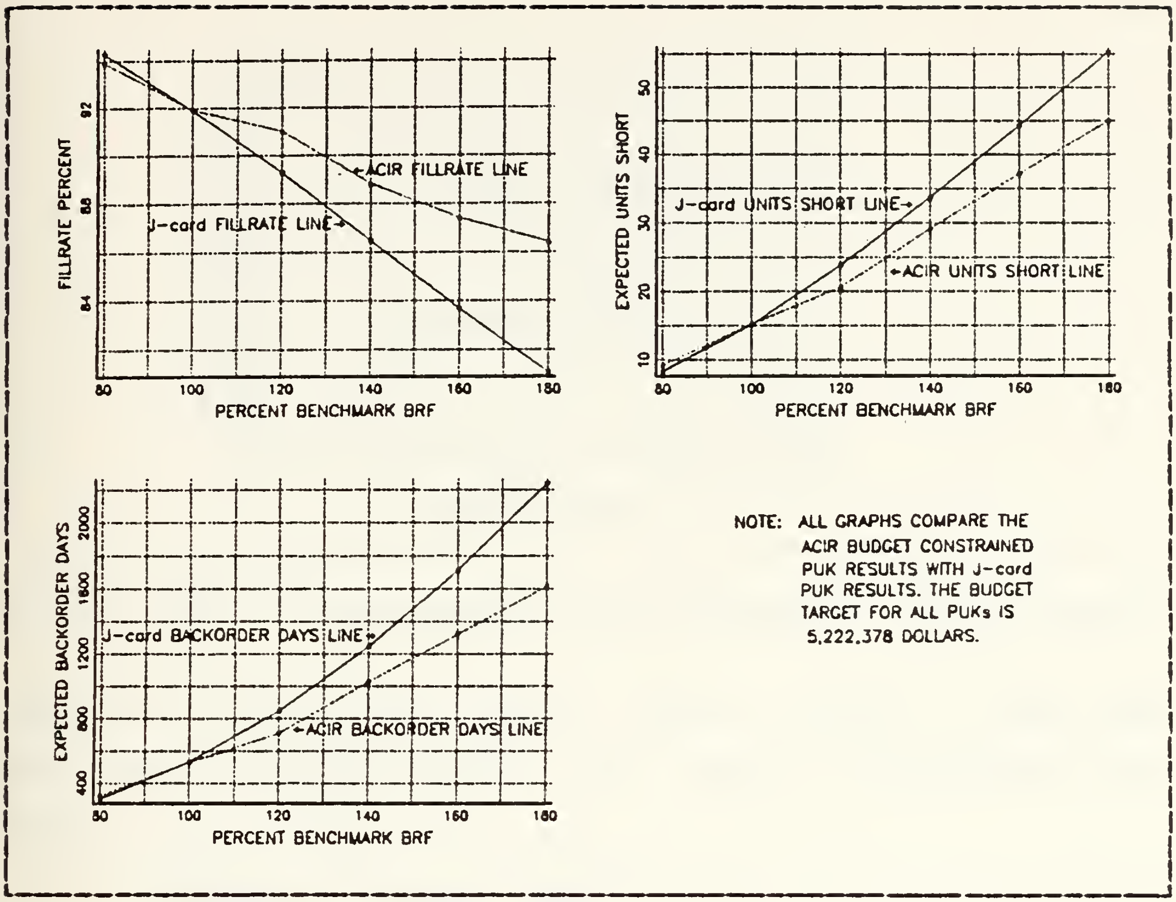

Figure 4.26 Performance Comparisons with Variable BRF.

that was depicted when the benchmark parametric values were used.

3. Effects of Varying MSRT

The comparisons here were again not generally intuitive. The achieved availabilities under the fixed-stockage (J-card) policy were always less than or equal to their ACIR counterparts as can be seen in Figure 4.27. However, as MSRT increased, all other performance statistics remained exactly at their benchmark values. Clearly these results posted by ACIM for the fixed-stockage (J-card) comparison policy do not reflect a true accounting of what one might

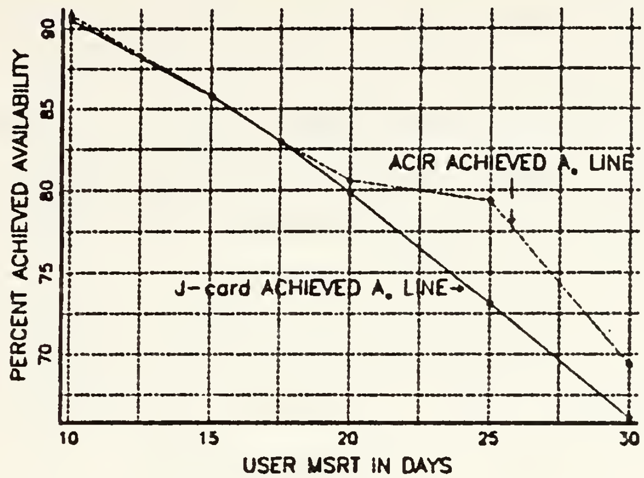

Figure 4.27 A_o Comparisons: Fixed Budgets, Variable MTTR.

expect with increasing MSRTs; since a change in user-MSRT must impact backorder days, fill rate, and expected units short.

4. Effects of Varying MTTR

The results in varying MTTR were analogous to those of varying the Operating Level (OL) parameter. As MTTR increased, maximum availability fell in the fixed-stockage (J-card) policy exactly as it did for the ACIR policy. However, achieved availability for the fixed-stockage (J-card) policy remained parallel to the ACIR policy. The fixed-stockage (J-card) policy was at all points only .03 percent lower than the ACIR policy. The rest of the performance statistics remained unchanged from benchmark values as the MTTR was varied.

F. MISCELLANEOUS FINDINGS

ACIM utilizes an override code system on its item data cards which enables the user to influence certain aspects of

the stockage and other computational results. The override code Y, is designed to tell ACIM that the part having this code is to be included in all model processes but a zero stock level is to be assigned for both the Availability Centered and Comparison Policies [Ref. 11]. However, the Y-coded items have a confusing effect on the concept of optimality.

The confusing impact on the concept of optimality by use of Y-coded items will be demonstrated via the effect on ACIR when a single item is changed from having no override code to having a Y override code. The item studied was the engine part number 6043T80601. In the benchmark case ACIR spares the PUK with one engine. When ACIM is allowed to spare while constraining availability to 82.4 percent the resultant investment is $5,222,378. If the engine is Y-coded, ACIR still uses the BRF of the engine in its maximum availability calculation. ACIR recognizes that the engine is in the data base for maximum availability computations, but ACIR is not allowed to spare this part. By adding this costraint, in order to be consistent with a notion of optimality, this should have the impact of ending with a solution that yields less availability per dollar invested; but this does not happen.

As previously stated, the engine is spared in the availability-constrained benchmark PUK, and the benchmark PUK cost $5,222,378. The achieved availability is 82.97 percent. When the engine is Y-coded and ACIR is again given an availability constraint of 82.4 percent, ACIM reports that the PUK required to reach an achieved operational availability of 83.26 percent can now be purchased for $4,619,378. This would imply that the original solution produced without Y-coding the engine was sub-optimal. The original solution is considered sub-optimal because the investment per unit of achieved availability is higher than when the engine is Y-coded.

The benchmark investment exceeds the case where the engine is Y-coded by exactly the price of the engine; however, the achieved operational availability of the benchmark case is slightly smaller. This shows that the solutions which are generated from data bases having dissimilar numbers of Y-coded items can not be directly compared and have the notion of optimality remain intact.

V. CONCLUSIONS

Ths sccpe of the problem that ACIM attempts to handle is enormous. In many regards the author was encouraged that ACIM may be able to provide scme insight intc how to prcperly spare the LAMPS MK III Pack-Up Kit (PUK). The enthusiasm of getting intuitively appealing results must however be tempered by the kncwledge of the modelling assumptions and scme specific examples that point to incongruous results.

The effects on LAMPS MK III PUK as the benchmark parameters were varied in the availability constrained scenarios are summarized as follows:

- stockage investment varies in the same direction and magnitude as unit cost changes;
- each ten percent increase in the BRF of all parts yields rcughly a $235,000 increase in investment;
- each ten percent increase in the operating level parameter yields a $132,000 increase in investment;
- each one day increase in user-MSRT yields a $130,000 increase in investment; and
- each one hour increase in MTTR increases investment by $278,000.

These are lccal results; that is, they are in the neighborhood cf values ACIM expects.

The effects on LAMPS MK III PUK achieved operational availability as the benchmark parameters were varied in the budget constrained scenarios are summarized as follows:

- each 10 percent increase in unit cost creates approximately a 3.65 percent decrease in achieved operational availability;
- each 10 percent increase in BRF of all parts yields roughly a 2.25 percent decrease in achieved operational availability;
- each 10 percent increase in the operating level is accompanied by a 1.3 percent decrease in achieved operational availability;
- each one day increase in user-MSRT yields about a one percent decrease in achieved operational availability; and
- each one hour increase in MTTR decreases achieved operational availability by approximately 2.1 percent.

These ,again, are local results.

The comparisons between achieved operational availability for the budget constrained optimizations of the LAMPS MK III PUKs and those PUKs whose inventory level is frozen yield some surprising results. The comparison between achieved operational availability shows that the PUK that retains a fixed level of inventory yields only slightly sub-optimal results in most cases. The performance statistics generated by the fixed-stockage comparison policy and ACIR are not generally comparable. The conclusion was that the user should place low confidence in ACIM's ability to perform a meaningful comparison between ACIR results and the fixed-stockage policy as defined in this study.

The results of the performance statistics were troublesome in the scenarios where the user-MSRT was varied. The counter-intuitive directions of the performance statistics lines were not the result of unanticipated marginal trade-offs unique to the LAMPS MK III data base. This was shown by letting the price of all items and the BRF of all items in the availability centered allowance to be of uniform value and observing that all trends in the Statistical Summary Report remained the same as with the unaltered LAMPS MK III data. That is, as user-Mean Supply Response Time (MSRT) increased backorder days decreased, fillrate increased and expected units short decreased. This implies that as user-MSRT increases performance gets better. Therefore, the model outputs for the performance statistics should be considered unreliable.

The analyst using the operating level parameter to reflect changes in operating tempo should be aware that a given percentage change in the operating level parameter is not identical with applying that same given percentage change uniformly accrcss the Best Replacement Factor of all the items in the item data base (I-cards).

ACIM in this single-echelon, single-site environment can give the user some insight into complex interrelationships that exist among the parts contained in the availability centered allowance of the LAMPS MK III. The results of ACIM should not be taken literally but should be taken as supplemental analysis to be used as an input to the LAMPS sparing problem. The difficulties with developing a suitable data base and the general reservations previously expressed about the availability calulation do not render the model unusable; but, the user must be aware of the limitations and restrictions imposed by the use of ACIM as a decision aid for sparing.

APPENDIX A
INPUT DATA

There are two general classes of data are defined as inputs to the Availability Centered Inventory Model, system-related data and item-related data. The system-related data is a file with records in different formats which give policy parameters, default values, model options, and definitions of sites involved in the operation/support of the equipment. The item-related data gives a variety of factors that define and describe individual parts within the equipment. A basic set of item data is given in one file, with additional item data being given (optionally) in a second file. The various input files and included record formats are identified as follows:

System Data File:

- Format A - Options and Default Values
- Format FA - COSAL Policy Parameters
- Format FB - .42 Provisioning Parameters
- Format FC - UICP Wholesale Policy Parameters[13]
- Format L - Site Data

Item Data File:

- Format I - Basic Item Factors

Additional Item Data File (Optional):

- Format J - MSRT Parameters and Specified Levels

For a few data elements, default values are automatically inserted by the model if not given in the input data. These data elements and their default values are identified in the data definitions given below. Also, whenever a data element conforms exactly to one contained in the Supply

---

[13]FB and FC are not used or discussed in this thesis.

Management Program Standard Data Element Dictionary, (NAVSUP Publication 508, DEN Dictionary) the DEN reference will be cited and a brief description will be given in the data definitions below.

1. <u>SYSTEM DATA FILE</u>

The System Factors file contains three different formats as illustrated above. The formats are identified by an alphabetic letter in column one of each record. All of the records are eighty columns long. They are arranged in sequence according to the format identification in column one.

FORMAT A - OPTIONS AND DEFAULT VALUES. There is one record in this format and it must always be first in the Systems Factor file. Included data elements provide default values for various parameters and controls used by the model. If the model is run interactively, some of these data elements may be changed during the session. Data elements given in Format A are defined as follows:

FORMAT INDENTIFICATION. An "A" is inserted in the first column to identify this format.

RUN INDENTIFICATION. Text entered in this field is printed at the top of all output reports to identify the particular run of the model.

OPTIONS. Entries in these fields control various features or operations of the model. Currently, the first four of the ten option fields are defined as follows:

1. MEC INPUT TYPE. This Option Is left blank if the MEC codes (1 = vital, 3 = nonvital) are to be used. If any mark (e.g., "X") is entered, then MCO codes (values = 1 - 5) are assumed to have been entered instead.

2. MEC USE. If any mark is entered (e.g., "X"), then the MEC codes will be used in the optimizing procedure. If left blank, all items will be assumed equally essential in the optimization.

3. DEFAULT MSRT. If left blank, the default MSRT's (defined below) for user sites are assumed to include the Order and Ship Time (O&ST) as well as expected delays due to shortages of higher-level stocks. If any mark is entered (e.g., "X"), then the O&ST is excluded from this factor (the model will add the O&ST from Format L data, defined below to the Default MSRT).

4. LEVELS FORMAT. If this is left blank then Format K results from previous use of ACIM. Any mark will envoke the case of Format J.

EQUIPMENT MTTR. Enter the Mean-Time-to-Repair the equipment upon failure, in days. This is the time required to accomplish the repair assuming all required repair parts are immediately available.

A TARGET. Enter the operational availability target as a fraction (including the decimal point). The model will build up stockages until this target or the investment target, given below, is first reached.

INVESTMENT TARGET. Enter the investment target, in thousand of dollars, in this field. Enter a large number (e.g., "9" in all columns) if reaching the availability target first is to be insured.

COST-EFFECTIVENESS CONTROLS. These fields are used to control the production of the Cost-Effectiveness report. In general, the optimization algorithm operates in an iterative fashion, each time adding one unit

to stock. As a unit is added to stock, a line of data may appear on the Cost- Effectiveness report if any one of the conditions based upon the following data occurs:

DELTA UNITS. A line of data is produced for every nth unit added to stock, where n is specified in this field (e.g., if a 5 is entered, then a line of data appears on the report for every fifth unit added to stock.)

DELTA A . A line of data is produced whenever the achieved A first exceeds an intergral multiple of this value. For example, if .05 is entered, then a line of data appears whenever the Ao reaches .05, .10, .15, .20, ...etc.

DELTA $. A line of data is produced whenever the achieved investment first exceeds an integral multiple of this value. For example, if 1000 is entered, then an line of data appears whenever the total investment reach 1000, 2000, 3000, ...etc., dollars.

PART NUMBER FIELD SIZE. In the Part Number/Nomenclature field of the Item Data records, the left-hand side is used for Part Number and the right-hand side is used for Nomenclature. Since the Part Number may vary in size from one application to another, the number of positions used is specified in this field.

RESPONSE TIMES. This is the average length of time, in days, required for a user of the equipment to obtain resupply from a higher supply source. There are two entries, one for Navy COG items, one for DLA COG items. The response times include administrative and transportation delays, and also a delay attributable to the

chance that the higher supply source may be out of stock. In most applications of the model, these response times are set by management as Navy standards. These factors and the Depot PLT and Depot Repair Cycle factors in the next two fields are used if COSAL levels only are to be calculated by the model; for multi-echelon applications, equivalent values are determined by the model itself.

DEPOT PLT. A default value for depot procurement lead time (total time reuired to procure material from a manufacturer) is entered here, in days. This value is used whenever the procurement lead time field in the Additional Item Data file is left blank.

DEPOT REPAIR CYCLE. A default value for the depot repair cycle, in days, is entered in this field. This value is used whenever the depot repair cycle field in the Additional Item Data file is left blank.

SCRAP RATE. A standard scrap rate is entered in this field as a fraction (e.g., 0.05). This is used as a default whenever the corresponding field in the Additional Item Data file is left blank.

FORMAT FA - COSAL POLICY PARAMETERS. There is only one record in the "FA" format; it gives factors needed for operation of the MCO and FLSIP COSAL policies. The data elements are defined as follows:

IDENTIFICATION. An "FA" is entered to identify this format.

TYPE OF DATA. Two words "COSAL PARAM." are entered to identify the type of data entered on this format.

MCO FORMULA PARMETERS. Three factors used as coefficients in the MCO risk formula are provided in these fields.

MCO RISK FLOORS. Minimum values for the risk factors calculated by the MCO risk formula are entered in these fields for the 4 values of MCC code.

MCO RISK CEILINGS. Maximum values for the risk factors calculated by MCO risk formula are entered in these fields for the 4 values of MCC codes.

FLSIP PARAMETER. A parameter used by the FLSIP COSAL policy is entered in this field. This parameter represents an annual demand threshold for stocking an insurance level for essential items.

CNA Policy Parameter. A parameter used by the CNA COSAL policy is entered in this field. This parameter represents an annual demand threshold for stocking an insurance level for essential items.

FORMAT L - SITE DATA. There is one record in the "L" format for each different kind of user or higher level maintenance/supply activity in the support system for the equipment. The model is limited to ten such activities; thus, the number of Format L records must be ten or less.

IDENFICICATION. An "L" is entered to identify this format.

SITE NAME. Any text that identifies the site may be entered here (entry is optional).

INDENTURE LEVEL: Records for top-level sites must have an Indenture Code of 1, the next-lower site Indenture Code of 2, etc. This continues down the support system hierarchy until lowest level (user) sites are reached.

ECHELON. In a multi-echelon support system, the echelon at which this site is positioned is entered here. For COSAL computations only, just user sites are defined in the "I" format and a "1" is entered in this field.

STOCKAGE FACILITY. If the site maintains inventories of spares enter any mark.

REPAIR FACILITY. If the site accomplishes shop maintenance enter any mark.

LEAD TIME. The average length of time required, in days, for this site to obtain resupply from a higher supply source assuming that supplies are immediately available at the supply source. If COSALs only are to be calculated and Option 3 is left blank, then a "0" must be entered since this factor is included in the average response times given in "A" format data.

REPAIR CYCLE. Enter the average repair cycle, in days, for items that are normally repaired at this site.

NUMBER OF LOCATIONS. Enter a "1" if COSALs only are to be computed. In a multi-echelon case, the number of different locations represented by the site is entered.

NUMBER OF EQUIPMENTS. Enter the number of equipments to be supported at the site. A "0" is entered for non-user sites. This factor is usually the one which causes one site to be distinguished from another.

COMPARISON POLICY. One of the following codes is entered to identify the Comparison Policy to be used:

1 - 25 FLSIP

2 - CNA COSAL

3 - MCC COSAL

30 - .42 Provisioning

31 - UICP Wholesale

50 - Provided by Format J input

51 - Protection Level

ACIR POLICY. Code "O" for Optimization, "E" for Enhanced, and "F" for Fixed (freeze comparison policy levels).

OPERATING FACTOR. This is identified at the bottom of in the II.C.2 as the variable OL.

LEVELS OUTPUT FORMAT. Entries in this field are operative only if Format J is selected and then the comparison policy level is output.

2. <u>ITEM DATA FILE</u>

The Item Data file contains one record for each item of the equipment to be included in the operation of the model. Even though data corresponds to values of an Override Code given as one of the data elements; the length of the records in this file must be at least eighty columns.

FORMAT IDENTIFICATION. An "I" is entered in this column to identify the record format.

REFERENCE NUMBER. The entry in this field is used to identify the item and its position in the parts breakdown of the equipment. Any one of several coding schemes may be used as long as the item records, when sorted on this field and the Part Number field defined below, are in top-down, breakdown sequence. The field may be left blank if the records in the item data file are positioned in top-down, breakdown sequence.

INDENTURE. A number (1 - 9) is entered in this field according to the indenture level of the item in the parts breakdown of the equipment. A "1" is always

entered in the first item record which represents the equipment itself.

PART NUMBER (DEN D046D/C002B). Enter the NIIN/NCN or other part or stock number, if available, for item identification purposes. Entries in this field are optional insofar as model operations are concerned. The maximum size of part mumbers entered is specified by field size given by Format A data. The rest of the Part Number/Nomenclature field is assumed to be used for Nomenclature.

NOMENCLATURE (DEN C004). Enter textual data that identifies or describes the item. Entries are optional in this field.

COGNIZANCE CODE (DEN C003). Enter a code identifying the management cognizance of the item.

NUMBER PER NEXT HIGHER ASSEMBLY (DEN D011). Enter the number of units of the item in its next higher assembly. If left blank, a default value of "1" is inserted.

UNIT COST (DEN B053). Enter the estimated unit procurement cost of the item in dollars and cents. There is an implied decimal point in this field, with the last two columns representing the cents portion of the cost.

SM&R CODES (DENS D012/D013/D013C). The Source, Maintenance, and Recoverability codes are given as defined in the DEN Dictionary. Entries for the Maintenance codes are mandatory; entries for the Source and Recoverability codes are optional.

BRF (DEN F027). The Best Replacement Factor, as defined in the DEN Dictionary, is entered in this field, with the last 4 positions of the field being to the right of an implied decimal point.

MRU (DEN C007). Enter a value for the Minimum Replacement Unit if different than 1. If left blank, a default value of "1" is assigned by the model.

MEC (DEN C008E). Enter a value for Military Essentiality Code, as defined in the DEN Dictionary, in this field. MCC codes for the MCO COSAL policy may be entered instead, but if so, Option 1 must be non-blank. Whichever coding scheme is entered and identified by Option 1, the model will make conversions if needed for the operation of the specified Comparison Policy.

OVERRIDE CODE (DEN C007B). If one of the following codes is entered in this field, the indicated action will be taken by the model:

Code	Action
W	The stock level for the item at user sites must be at least as much as the Override Amount given in the next field. In both the Comparison and ACIR policies, the value given by the Override Amount is used as the stock level if it is larger than the amount calculated by the policy.
X	The item is completely eliminated from all processes of the model except for input/output functions.
Y	The item is included in all model process but a zero stock level is assigned for

both the Availability Centered and Comparison Policies.

Z The item is included in all model processes but the value given by the Override Amount is used as the stock level at user sites for both the Availability Centered and Comparison Policies.

OVERRIDE AMOUNT (DEN C007A). The amount entered in this field is used as the stock level if a "Z" Override code is assigned or minimum stock level if a "W" Override code is assigned.

3. ADDITIONAL ITEM DATA FILE

The following is a brief description of the modified input format for the optional data cards which are referred to as the J-CARDS. These cards are referred to as J-CARDS because the character in the first column is 'J' to identify them as such. This modification applies only to the NPS implemented version of ACIM. This modification was undertaken by LT Henry Watras to enable the existing ACIM program input requirements to be compatible with the PL/1 complier installed in the IBM 3033 system at NPS. Also, this modification allowed for ten different sites in a support organization when using ACIM to compare user-inserted site provisioning stocks.

The following JCARDS format is further explained in the ACIM 2.0 Handbook [Ref. 12].

Cols	Data Element	MODE	Unit
1	Format ID (J)	A	
2-11	Item Ref	AN	
12	Edit Reference	I	

13-17	User MSRT	R	Days
18-21	Procurement Lead Time	R	Days
22-24	Deport Repair Cycle	R	Days
25-28	Scrap Rate	R	Fraction
29-34	Annual Wholesale Demand	I	Units Per Year
35-38	Wholesale Stock Level	I	Units
	Specified Stock Levels for Specific Site		
40-43	Site 1	I	Units
44-47	Site 2	I	Units
48-51	Site 3	I	Units
52-55	Site 4	I	Units
56-59	Site 5	I	Units
60-63	Site 6	I	Units
64-67	Site 7	I	Units
68-71	Site 8	I	Units
72-75	Site 9	I	Units
76-79	Site 10	I	Units

where:

A signifies latter character;

AN signifies alpha-numberic character;

R signifies a real number;

I signifies an integer number.

APPENDIX B

BENCHMARK I-CARDS FOR LAMPS MK III

These data reflect the I-card data received from the Center for Naval Analysis and the benchmark item data used in this study. The part numbers were eliminated and the spacing between elements condensed so that these input cards are in a more easily read format. Appendix C provides representative I-cards exactly as they appeared for the benchmark cases.

I	01	SH60B				100	296.989	Y
I	382	RADIO RCVR AS	1R	1	1680000	OG	0.8528	11
I	1092	RCVR-XMTR,UHF	1R	2	937000	OG	1.3659	11
I	1102	CONTROL,UHF R	1R	1	270000	OG	1.5642	11
I	1112	BASE MOUNTING	1R	2	13500	OG	0.0537	11
I	1122	SPCH,SCRTY EQ	1R	1	541000	OL	4.2000	11
I	1132	RCVR-XMTR,HF	1R	1	1300000	OG	5.5629	11
I	1142	AMPLIFER-COUP	1R	1	1300000	OG	5.5629	11
I	1152	MOUNT,RCVR-XM	1R	1	216000	OG	0.0537	11
I	1162	MOUNT, AMP-CO	1R	1	75600	OG	0.0537	11
I	1172	CONTROL,HF RA	1R	1	270000	OG	0.5809	11
I	1212	CONVERTER-PRO	1R	1	24700000	OG	2.8571	11
I	1222	CONTROL INDIC	1R	1	5750000	OG	2.2281	11
I	1232	RMT SWITCHING	1R	4	1080000	OG	0.4701	11
I	1242	INTERCONN. BO	1R	2	146000	OG	0.1960	11
I	1252	RELAY ASSY	1R	1	562000	OG	0.6742	11
I	1262	APX100TRNSPDR	1R	1	1670000	OG	0.7616	11
I	1272	CMPTR,TRANSPN	1R	1	166000	OL	1.5273	11
I	1322	BLANKER INTFC	1R	1	981000	OG	0.8187	11
I	1332	PROC,SPCH SEC	1R	1	658000	OL	0.8624	11
I	1342	REM CNTRL UNT	1R	1	76300	OL	0.1808	11

I	1352	COMM SCTY EQP	1R	1	732000	OL	0.3629	11
I	1362	STD ABN CMPTR	1R	1	22000000	OG	3.5146	11
I	1372	CONV-MULTIPLE	1R	1	21000000	OG	3.4711	11
I	1382	CONTROL IND (	1R	1	4810000	OG	1.7143	11
I	1392	CONTROL IND (	1R	1	4810000	OG	1.7143	11
I	1402	TAPE CONTRCL	1R	1	11400000	OG	2.1000	11
I	1412	TAPE HANDLING	1R	1	1830000	OG	11.2000	11
I	1422	CONTRCL MCNIT	1R	1	2560000	OG	0.2543	11
I	1542	RDR NAVIGATIO	1R	1	15300000	OG	1.3884	11
I	1552	DISPLACEMENT	1R	2	2850000	OG	1.6901	11
I	1562	ELECTRONIC CT	1R	2	1740000	OG	2.6837	11
I	1572	CMPS SYS CNTR	1R	2	309000	OG	0.3745	11
I	1582	XMTR RMT CMPS	1R	2	87500	OG	0.6965	11
I	1592	RCVR/TRANSMIT	1R	1	1470000	OG	1.1009	11
I	1602	CONTROL, RCVR	1R	1	130000	OG	0.0607	11
I	1612	SHCKMNT,BASE	1R	1	95000	OG	0.0537	11
I	1622	RCVR/TRANSMIT	1R	1	1220000	OG	2.2047	11
I	1632	INDICATOR,HEAD	1R	2	414000	OD	1.6216	11
I	1642	ANTENNA	1R	2	130000	OZ	0.0152	11
I	1652	ANTENNA	1R	1	486000	OG	0.1622	11
I	1662	AMPL RELAY AS	1R	1	443000	OG	0.1762	11
I	1672	MOUNTING	1R	1	60000	OG	0.0093	11
I	1682	RECEIVER, RAD	1R	1	384000	OG	0.5870	11
I	1692	MOUNTING	1R	1	13500	OG	0.0537	11
I	1702	NAV SWITCH-IN	1R	1	11000000	OG	2.8866	11
I	1712	BRG DIS HD IND	1R	2	2010000	OG	0.9825	11
I	1722	ATTITUDE IND	1R	2	1180000	OG	0.9825	11
I	1732	CONVERTER DIS	1R	2	11500000	OG	1.4359	11
I	1762	CLOCK,AIRCRAF	1R	1	70800	OG	0.7749	11
I	1772	LIGHT CONTROL	1R	1	458000	OG	0.1283	11
I	1782	ANTENNA,UHF/T	1R	2	215000	OZ	0.1120	11
I	1792	ANTENNA,IFF	1R	3	114000	OZ	0.0560	11
I	1802	ANTENNA,SCNOB	1R	1	131000	OZ	0.1120	11
I	1822	FITTING ASY	1R	1	80600	OG	0.2800	11
I	1832	FITTING ASY	1R	1	80600	OG	0.2800	11

I	1842	FITTING ASY	1R	1	77000	OG	0.2800	11
I	1852	FITTING ASY	1R	1	77000	OG	0.2800	11
I	1862	SHROUD ASSY	1R	1	117604	OG	0.0093	11
I	1872	WINDOW	1R	1	112000	OZ	0.9101	11
I	1882	LINER	1R	1	93800	OZ	0.0700	11
I	1892	LATCH ASSY	1R	1	83900	OZ	0.4433	11
I	1902	NUT ASY LCK	1R	1	132740	OZ	0.4901	11
I	1912	APEX FTTG A	1R	1	92400	OZ	0.2800	11
I	1922	APEX FTTG A	1R	1	92400	OZ	0.2800	11
I	1932	BEARING ASS	1R	1	78320	OZ	0.4198	11
I	1942	BEARING ASS	1R	1	93010	OZ	0.2799	11
I	1952	CENT WINDSH	1R	1	95550	OZ	0.0279	11
I	1962	LATCH CONTA	1R	25	199380	OG	0.0117	11
I	1972	NUT ASSY	1R	1	74670	OZ	0.0088	11
I	1982	LOCK RING	1R	1	66000	OZ	0.0088	11
I	1992	FAIRING ASS	1R	4	37390	OZ	0.5600	11
I	2002	CAM	1R	4	75790	OZ	1.1667	11
I	2012	FIREWALL AY	1R	1	40351	OG	0.0088	11
I	2022	PANEL ASSY	1R	1	45760	OG	0.0088	11
I	2032	PANEL ASSY	1R	1	63467	OG	0.0088	11
I	2042	VIB ABSORBE	1R	1	423270	OG	0.0261	11
I	2052	WINDOW ASSY	1R	1	578420	OG	0.1167	11
I	2062	JETTISON LA	1R	2	364140	OG	0.0933	11
I	2072	STABILATOR	1R	1	1653640	OG	0.0870	11
I	2082	CENTER STAB	1R	1	2465120	OG	0.2100	11
I	2092	PIN ASSY	1R	2	126170	OG	0.6065	11
I	2102	SEAL ASSY	1R	1	872280	OG	0.5541	11
I	2112	PANEL ASSY	1R	1	918000	OG	0.0117	11
I	2122	BUCKLE AY	1R	3	66510	OZ	0.0174	11
I	2132	INERTIA REE	1R	3	63370	OG	0.0174	11
I	2142	LAP BELT AS	1R	6	35283	OZ	0.0174	11
I	2152	DRAG BEAM A	1R	1	1079620	OG	0.1306	11
I	2162	DRAG BEAM A	1R	1	1079620	OG	0.1306	11
I	2172	MLG SHOCK S	1R	2	598080	OG	0.3134	11
I	2182	MLG WHEEL A	1R	2	256680	OG	0.0088	11

I	2192	BRAKE	1R	2	278930	OG	0.5600	11
I	2202	MLG BRAKE A	1R	2	278930	OG	0.5600	11
I	2212	TAIL LANDG	1R	1	12558610	OG	0.0349	11
I	2222	TLG SHOCK S	1R	1	127500	OG	0.1393	11
I	2232	TOR ARM ASS	1R	2	63750	OG	0.0088	11
I	2242	LOCK PIN AS	1R	1	48540	OG	0.1742	11
I	2252	WHEEL & TIR	1R	2	114560	OG	0.0261	11
I	2262	T1 WHL LK A	1R	1	246499	OD	0.1742	11
I	2272	MASTER BRAK	1R	4	89390	OG	0.0088	11
I	2282	SLAVE VALVE	1R	2	46370	OG	0.0088	11
I	2292	VALVE	1R	1	78120	OG	0.0088	11
I	2302	RAST PANEI	1R	1	894450	OD	0.2858	11
I	2312	RAST ACTUAT	1R	1	1249970	OD	1.6092	11
I	2322	MAIN PROBE	1R	1	9305710	OG	2.5225	11
I	2332	PROBE HOIST	1R	1	6373880	OG	0.9333	11
I	2342	PROBE ACTUA	1R	1	786920	OD	0.9333	11
I	2352	ELECTRONIC	1R	1	13720	OD	0.1633	11
I	2362	TIE ROD	1R	1	147560	OG	0.1680	11
I	2372	PUSH ROD	1R	1	65750	OG	0.0117	11
I	2382	YOKE&HOUSIN	1R	1	255300	OZ	0.0560	11
I	2392	YOKE&HOUSIN	1R	1	231300	OZ	0.0560	11
I	2402	BEAM ASSY	1R	1	443680	OG	0.0174	11
I	2412	BELLCRANK A	1R	2	37440	OG	0.0280	11
I	2422	BELLCRANK A	1R	1	42200	OG	0.0280	11
I	2432	BELLCRANK A	1R	1	42200	OG	0.0280	11
I	2442	BELLCRANK A	1R	1	51040	OG	0.0840	11
I	2452	BELLCRANK A	1R	1	49180	OG	0.1680	11
I	2462	ROD ASSY	1R	1	113030	OG	0.0261	11
I	2472	LINK ASSY	1R	1	155460	OD	0.0088	11
I	2482	SHAFT ASSY	1R	1	17710	OZ	0.0435	11
I	2492	CAPSULE ASS	1R	2	114540	OZ	0.0088	11
I	2502	TAIL ROTOR	1R	1	3217260	OG	0.1393	11
I	2512	QUADRANT AS	1R	1	302290	OG	0.1680	11
I	2522	TAIL ROTOR	1R	1	3707700	OG	0.1680	11
I	2532	ACTUATOR	1R	2	1001400	OD	1.2192	11

I	2542	STAB INDICA	1R	2	159020	OD	0.0784	11
I	2552	BELLCRANK A	1R	1	20520	OG	0.0560	11
I	2562	BELLCRANK A	1R	1	68810	OG	0.2182	11
I	2572	ADJUSTER AS	1R	1	456250	OG	0.1680	11
I	2582	ADJUSTER AS	1R	1	455530	OG	0.1680	11
I	2592	PUSH ROD	1R	2	31359	OG	0.2799	11
I	2602	PEDAL ASSY	1R	2	75930	OG	0.1680	11
I	2612	PEDAL ASSY	1R	2	75930	OZ	0.1680	11
I	2622	SUPPORT	1R	2	15872	OZ	0.2239	11
I	2632	SWITCH	1R	2	68200	OZ	0.2239	11
I	2642	SWITCH	1R	2	76500	OG	0.2239	11
I	2652	BELLCRNK AS	1R	1	22737	OZ	0.0840	11
I	2662	COLL STK AS	1R	1	508090	OG	0.4480	11
I	2672	COLL STICK	1R	1	532870	OG	0.4480	11
I	2682	CYCLC STK A	1R	2	62400	OG	0.3359	11
I	2692	BELLCRANK A	1R	2	20790	OG	0.1120	11
I	2702	BELLCRANK A	1R	1	56530	OG	0.1400	11
I	2712	CONTROL ASS	1R	1	84100	OG	0.6354	11
I	2722	BELLCRANK	1R	1	20350	OG	0.0280	11
I	2732	LINK ASSY	1R	1	30480	OG	0.1680	11
I	2742	SERVO ASSY	1R	1	5568	OD	0.1742	11
I	2752	OUTPUT LEVE	1R	1	37630	OG	0.0840	11
I	2762	INPUT LEVER	1R	1	32960	OG	0.0840	11
I	2772	COUPLING	1R	1	50750	OG	0.0840	11
I	2782	LINK ASSY-M	1R	1	10860	OG	0.0840	11
I	2792	BELLCRANK	1R	1	52110	OG	0.1680	11
I	2802	PITCH BELIC	1R	1	30920	OG	0.1680	11
I	2812	ROD ASSY	1R	1	30920	OG	0.1680	11
I	2822	LINK ASSY-M	1R	1	34830	OD	0.0560	11
I	2832	LINK ASSY-M	1R	1	10860	OG	0.0840	11
I	2842	LINK ASSY-M	1R	1	10860	OG	0.0840	11
I	2852	LINK ASSY-M	1R	1	10860	OG	0.0840	11
I	2862	PRIMARY SER	1R	3	4355190	OD	0.6442	11
I	2872	PUSH ROO ASSY	1R	1	61400	OD	0.1400	11
I	2882	PUSH ROO ASSY	1R	1	81200	OD	0.1400	11

I	2892	PUSH ROO ASSY	1R	1	97530	OD	0.1400	11
I	2902	ROLL TRIM A	1R	1	3551120	OG	0.2874	11
I	2912	PITCH TRIM	1R	1	4434900	OG	0.1567	11
I	2922	SERVO ASSY	1R	2	2133970	OG	0.1742	11
I	2932	CONTROL ASS	1R	1	5352470	OG	0.0174	11
I	2942	TRIM ACTUAT	1R	1	2404810	OD	0.2874	11
I	2952	ACTUATR,C T	1R	1	5472290	OD	0.6354	11
I	2962	SHAFT ASSY	1R	1	148590	OG	0.0840	11
I	2972	LATERAL SHA	1R	1	116450	OG	0.0560	11
I	2982	SHAFT ASSY	1R	1	130230	OG	0.0560	11
I	2992	MANFLD/VLV	1R	1	155180	OZ	0.0957	11
I	3002	ACCUMULATCR	1R	1	149020	OZ	0.1003	11
I	3012	ROTOR SPEED	1R	1	98930	OZ	0.8400	11
I	3022	BLADE FOLD	1R	1	62260	OG	0.0583	11
I	3032	BRACKET ASS	1R	4	292990	OD	0.0233	11
I	3042	CONE, MRH	1R	1	25200	OZ	0.0088	11
I	3052	BIFILAR ASS	1R	1	2110500	OG	0.0088	11
I	3062	ROD ASSY	1R	4	167340	OG	0.1916	11
I	3072	PITCH ROO	1R	4	351360	OD	0.0958	11
I	3082	CYLINDER AS	1R	4	88820	OD	0.3966	11
I	3092	DAMPER ASSY	1R	4	566690	OG	0.5837	11
I	3102	HINGE	1R	1	1731290	OG	0.2450	11
I	3112	HINGE	1R	1	1731290	OG	0.2450	11
I	3122	HINGE	1R	1	1731290	OG	0.2450	11
I	3132	HINGE	1R	1	1731290	OG	0.2450	11
I	3142	PITCH HORN	1R	4	211260	OD	0.0349	11
I	3152	LOCK PIN AS	1R	8	175910	OG	0.2800	11
I	3162	BEARING ASS	1R	4	1488530	OD	0.5398	11
I	3172	BEARING ASS	1R	4	1410560	OD	0.5742	11
I	3182	PLATE ASSY	1R	1	204760	OD	0.0349	11
I	3192	PLATE, PRES	1R	1	400330	OG	0.0349	11
I	3202	FLAP ASSY	1R	4	286940	OG	0.0261	11
I	3212	STOP ASSY	1R	4	99450	OG	0.0933	11
I	3222	CAM ASSY	1R	4	75790	OZ	0.8400	11
I	3232	SWSHPLT	1R	1	3395720	OG	0.0870	11

I	3242	SCISSORS AS	1R	2	318090	OG	0.0609	11
I	3252	MAIN RTR BL	1R	4	9841440	OG	1.6970	11
I	3262	TIP CAP ASS	1R	4	229690	OG	0.6273	11
I	3272	BIM INDCTR	1R	4	98420	OG	0.2090	11
I	3282	ROD	1R	4	47330	OG	0.1671	11
I	3292	ROD END ASS	1R	4	15960	OG	1.6800	11
I	3302	ROD END ASS	1R	4	15600	OG	0.4198	11
I	3312	PITCH BEAM	1R	1	87900	OG	0.5600	11
I	3322	TAIL BLADES	1R	2	4746280	OG	0.0870	11
I	3332	ACCUMULATOR	1R	1	939840	OG	0.4901	11
I	3342	ACTUATOR, B	1R	4	1526020	OD	0.3733	11
I	3352	PITCH LOCK	1R	4	406240	OD	0.1867	11
I	3362	PITCH LOCK	1R	4	159770	OG	0.0933	11
I	3372	MOTOR, INDE	1R	1	2194100	OD	0.2800	11
I	3382	BLADE FOLD	1R	1	796510	OG	0.2566	11
I	3392	GENERATOR,	1R	1	1054810	OD	0.2090	11
I	3402	ACCUMULATOR	1R	1	885880	OG	0.1132	11
I	3412	EXHAUST DUC	1R	1	140010	OG	0.2239	11
I	3422	CBL RESCUE	1R	1	79240	OZ	0.0280	11
I	3432	RELAY	1R	2	84414	OZ	0.0467	11
I	3442	SHAFT ASSY	1R	2	242974	OG	0.0700	11
I	3452	STRAINER	1R	1	101370	OZ	0.0560	11
I	3462	FLANGE	1R	1	219300	OZ	0.0088	11
I	3472	SHAFT ASSY	1R	1	701250	OZ	0.2239	11
I	3482	FLANGE ASSY	1R	1	104520	OZ	0.0088	11
I	3492	BRAKE DISC	1R	1	39860	OZ	0.2601	11
I	3502	OIL PRSR SW	1R	1	113090	OZ	0.2874	11
I	3512	STATOR	1R	1	86160	OZ	0.0280	11
I	3522	ROTOR	1R	1	246220	OZ	0.0280	11
I	3532	GEAR BOX AS	1R	2	2070510	OG	0.2525	11
I	3542	TAIL SHAFT	1R	1	70180	OD	0.0088	11
I	3552	GEAR BOX AS	1R	2	7241390	OG	0.8100	11
I	3562	FLANGE ASSY	1R	2	75460	OD	0.0088	11
I	3572	MAIN GEAR B	1R	1	22388496	OG	0.0088	11
I	3582	PUMP	1R	2	230490	OD	0.0609	11

I	3592	FILTER ASSY	1R	1	121400	OG	0.0088	11
I	3602	SHAFT ASSY	1R	2	429850	OD	0.4875	11
I	3612	SHAFT ASSY	1R	1	59260	OD	0.0088	11
I	3622	INTER GEAR	1R	1	2586450	OG	0.0261	11
I	3632	TAIL GEAR E	1R	1	5190220	OG	0.1916	11
I	3642	ACTUATOR	1R	1	630160	OG	0.0933	11
I	3652	COUPLING	1R	1	826200	OG	0.0840	11
I	3662	PLATE ASSY	1R	1	928800	OD	0.1680	11
I	3672	T/R DRIVE S	1R	3	841950	OG	0.0174	11
I	3682	SHAFT	1R	1	297730	OD	0.1342	11
I	3692	JAW ASSY	1R	1	165850	OG	0.0420	11
I	3702	COUPLING AS	1R	1	852320	OG	0.2275	11
I	3712	TUBE ASSY	1R	2	105170	OG	0.2239	11
I	3722	T/R DRIVE S	1R	1	234250	OD	0.0174	11
I	3732	RADIATOR	1R	1	685830	OG	0.0174	11
I	3742	FAN	1R	1	364650	OD	0.3221	11
I	3752	ROTOR BRAKE	1R	1	330710	OG	0.2275	11
I	3762	MASTER CYL	1R	1	298890	OG	0.0088	11
I	3772	VALVE	1R	2	114646	OZ	0.0336	11
I	3782	X BLEED VAL	1R	2	214220	OD	0.2525	11
I	3792	VALVE	1R	2	108308	OZ	0.0336	11
I	3802	DUCT ASSY	1R	1	57650	OG	0.0280	11
I	3812	ELECTRONIC	1R	1	1430760	OD	0.6354	11
I	3822	SOLENOID IN	1R	1	102210	OZ	0.0117	11
I	3832	VALVE	1R	2	74310	OZ	0.1680	11
I	3842	VALVE	1R	2	69060	OZ	0.1680	11
I	3852	VALVE	1R	2	74070	OZ	0.1050	11
I	3862	VALVE	1R	2	79600	OZ	0.1680	11
I	3872	VALV BREAKA	1R	1	311460	OZ	0.0088	11
I	3882	VALVE	1R	1	113900	OZ	0.0088	11
I	3892	GIMBL ENG M	1R	2	115520	OZ	0.1167	11
I	3902	EXCITER	1R	2	132242	OZ	0.0280	11
I	3912	SUPPRT ASSY	1R	1	19712	OG	0.1680	11
I	3922	CHECK VALVE	1R	1	88950	OZ	0.0088	11
I	3932	QUADRANT AS	1R	1	283510	OG	0.2239	11

I	3942	QUADRANT AS	1R	1	282260	OG	0.2239	11
I	3952	INPUT ASSY	1R	2	175520	OG	0.2239	11
I	3962	INPUT ASSY	1R	2	179330	OG	0.2239	11
I	3972	POTENTIOMET	1R	1	179090	OG	0.2239	11
I	3982	INLET ASSY	1R	2	2815960	OG	0.0840	11
I	3992	VALVE	1R	2	246720	OD	0.4437	11
I	4002	CROTCH ASSY	1R	2	223740	OG	0.2239	11
I	4012	VALVE	1R	2	257380	OD	0.3134	11
I	4022	SPEED SWITC	1R	1	82550	OZ	0.0840	11
I	4032	STARTER	1R	2	668630	OD	1.0012	11
I	4042	TAILPIPE AS	1R	2	49130	OG	0.0280	11
I	4052	EXHAUST ASS	1R	1	706250	OG	0.0280	11
I	4062	EXHAUST ASS	1R	1	777540	OG	0.0280	11
I	4072	R/H DUCT AS	1R	1	294430	OG	0.3267	11
I	4082	L/H DUCT AS	1R	1	218430	OG	0.3267	11
I	4092	DUCT	1R	1	50000	OG	0.4433	11
I	4102	DUCT	1R	1	49720	OG	0.0280	11
I	4112	DESWIRL DUC	1R	2	437910	OG	0.1867	11
I	4122	CABIN TEMP	1R	1	508900	OD	0.0840	11
I	4132	ICE CNTL UN	1R	1	138850	OG	0.0609	11
I	4142	COOLING FAN	1R	2	556660	OG	0.2400	11
I	4152	ECS CONT PA	1R	1	291050	OG	0.0163	11
I	4162	MODULATING	1R	1	1211480	OG	0.0840	11
I	4172	CONTROL UNIT	1R	1	4044030	OD	0.0840	11
I	4182	AIR CYCLE M	1R	1	3590050	OG	0.1855	11
I	4192	HEAT EXCHAN	1R	1	1394330	OG	0.0175	11
I	4202	WATER SEPER	1R	1	766010	OG	0.0420	11
I	4212	TEMP CONTRC	1R	1	563040	OG	0.0163	11
I	4222	ROTARY ACTU	1R	1	127460	OD	0.0828	11
I	4232	JUNCTION BC	1R	1	445300	OG	0.0198	11
I	4242	SIG CONVERT	1R	1	884040	OG	0.0840	11
I	4252	BRUSH ASSY	1R	1	163580	OZ	0.2239	11
I	4262	SLIP RING A	1R	1	876760	OG	0.0560	11
I	4272	DIST BOX AY	1R	1	2382000	OG	0.0261	11
I	4282	CABLE ASSY	1R	1	166940	OZ	0.0168	11

I	4292	HARNESS ASSY	1R	1	349580	OZ	0.0168	11
I	4302	HARNESS ASSY	1R	1	349580	OZ	0.0168	11
I	4312	HARNESS, ENG.	1R	1	437070	OZ	0.0840	11
I	4322	HARNESS, ENG.	1R	1	437070	OZ	0.0840	11
I	4332	PANEL ASSY	1R	2	134410	OG	0.1654	11
I	4342	S/O LIGHT	1R	1	50730	OG	0.0140	11
I	4352	LGTS DIMMER	1R	1	236210	OG	0.0560	11
I	4362	RELAY PANEL	1R	1	1573790	OG	0.3481	11
I	4372	MAIN GENERA	1R	2	1499210	OD	1.3146	11
I	4382	CONTROL UNIT	1R	3	375880	OD	0.5487	11
I	4392	CONVERTER,	1R	2	913050	OD	0.0088	11
I	4402	COND ANALYZ	1R	1	868980	OD	0.2437	11
I	4412	BATTERY	1R	1	481710	OG	0.0697	11
I	4422	PROBE LIGHT	1R	2	49610	OG	0.0233	11
I	4432	LDG/HVR LIG	1R	2	49180	OG	0.0523	11
I	4442	LIGHT ASSY	1R	1	167100	OG	0.6273	11
I	4452	LIGHT ASSY	1R	1	47030	OG	0.0583	11
I	4462	LIGHT	1R	1	33820	OG	0..0560	11
I	4472	SDE PSTN LG	1R	1	4550	OG	0.2624	11
I	4482	DOME LIGHT	1R	3	56780	OG	0.4198	11
I	4492	ROTOR HD LI	1R	1	6160	OG	0.0082	11
I	4502	LIGHT ASSY	1R	2	97370	OG	0.1480	11
I	4512	LGT PWR SUP	1R	1	210320	OG	0.6704	11
I	4522	CABLE ASSY CO	1R	1	69100	OZ	0.0168	11
I	4532	CABLE ASSY CO	1R	1	69100	OZ	0.0168	11
I	4542	CABLE ASSY CO	1R	1	69100	OZ	0.0168	11
I	4552	CABLE ASSY CO	1R	1	69100	OZ	0.0168	11
I	4562	CABLE ASSY CO	1R	1	101720	OZ	0.0168	11
I	4572	CABLE ASSY CO	1R	1	101720	OZ	0.0168	11
I	4582	CABLE ASSY CO	1R	1	101720	OZ	0.0168	11
I	4592	CABLE ASSY CO	1R	1	101720	OZ	0.0168	11
I	4602	CABLE ASSY	1R	1	121264	OZ	0.0280	11
I	4612	CABLE ASSY	1R	1	115720	OZ	0.0280	11
I	4622	1 TRANSFER	1R	1	880638	OG	0.2400	11
I	4632	1 TRANSFER	1R	1	129410	OG	0.2400	11

I	4642	SERVO MANIF	1R	2	128150	OG	0.0088	11
I	4652	PUMP	1R	3	1507968	OG	0.8615	11
I	4662	TRANS MOD	1R	1	995260	OG	0.0609	11
I	4672	ASSIST MODU	1R	1	630830	OG	0.0784	11
I	4682	MODULE ASSY	1R	1	173870	OD	0.5600	11
I	4692	MOTOR	1R	1	409070	OD	0.2874	11
I	4702	HYDRAULIC V	1R	1	199770	OG	0.2239	11
I	4712	HYD RES PUM	1R	1	344760	OG	0.0435	11
I	4722	VALVE SELEC	1R	1	84000	OZ	0.1283	11
I	4732	PRIME SHUTC	1R	3	39550	OZ	0.1680	11
I	4742	RECP P/R/FU	1R	1	136080	OZ	0.0560	11
I	4752	VALVE ASSY	1R	2	331690	OD	0.8400	11
I	4762	SENSOR	1R	1	231530	OZ	0.1400	11
I	4772	VALVE	1R	1	249050	OZ	0.1680	11
I	4782	EXT PWR MCN	1R	1	97990	OZ	0.2239	11
I	4792	TEE CHECK V	1R	1	35400	OZ	0.0840	11
I	4802	PRIME PUMP	1R	1	305070	OG	0.1045	11
I	4812	FUEL VALVE	1R	1	63030	OD	0.2239	11
I	4822	FUEL VALVE	1R	1	63030	OD	0.2239	11
I	4832	SHUT-OFF VA	1R	1	232370	OG	0.2239	11
I	4842	FUEL PUMP	1R	1	857220	OG	0.0560	11
I	4852	FUEL CELL U	1R	2	85170	OG	0.2799	11
I	4862	FUEL SIGNAL	1R	1	379460	OD	0.0112	11
I	4872	LLW CONDITIT	1R	1	99970	OG	0.1400	11
I	4882	WIPER MOTOR	1R	1	135640	OZ	0.1480	11
I	4892	HANDLE	1R	1	80000	OZ	0.0840	11
I	4902	VALVE	1R	1	141370	OG	0.2799	11
I	4912	FIRE BOTTLE	1R	2	77040	OD	0.7401	11
I	4922	PANEL ASSY	1R	1	206210	OG	0.2799	11
I	4932	MISC SWITCH	1R	1	127800	OG	0.2100	11
I	4942	HOIST,R H P	1R	1	1816142	OG	0.1167	11
I	4952	RESC HOIST	1R	1	9347076	OG	0.2799	11
I	4962	ACCLEROMETE	1R	4	246610	OZ	0.1132	11
I	4972	ICE DETECTC	1R	1	313640	OD	0.0840	11
I	4982	PITOT TUBE	1R	2	352240	OZ	0.3359	11

I	4992	PILOT DISP	1R	2	1097580	OG	0.2437	11
I	5002	CENT DISP U	1R	1	2235140	OG	0.2264	11
I	5012	IVVI INDICA	1R	2	107300	OD	0.3047	11
I	5022	MODE SEL PA	1R	2	849580	OG	0.2320	11
I	5032	AIR SPEED IND	1R	2	90130	OD	0.2227	11
I	5042	CAUT ADV PN	1R	1	2353220	OG	0.0929	11
I	5052	ALTIMETER	1R	1	262548	OG	0.8485	11
I	5062	ALTIMETER	1R	1	388692	OG	0.8485	11
I	5072	CLOCK,MECHAN	1R	2	65556	OG	0.5091	11
I	5082	COMPASS,REMOT	1R	2	89316	OD	0.6176	11
I	5092	RT GYRO XMTR	1R	2	109512	OD	0.3000	11
I	5102	TRANSDUCER	1R	1	276940	OZ	0.1485	11
I	5112	DIG COMPUTE	1R	1	10533840	OD	1.2903	11
I	5122	SAS AMPL	1R	1	2593810	OD	0.1206	11
I	5132	PANEL ASSY	1R	1	236990	OG	0.0093	11
I	5142	STAB AMP AS	1R	2	1662300	OG	0.8917	11
I	5152	SENSOR ASSY	1R	1	628660	OG	0.4198	11
I	5162	GYROSCOPE	1R	4	494010	OD	0.4921	11
I	5172	TEST POINT	1R	1	188320	OG	0.0093	11
I	5182	MNTG BASE	1R	1	48500	OZ	0.0093	11
I	5192	HOVER CONTR	1R	1	60190	OG	0.6136	11
I	5202	CONTROL PNL	1R	2	1768070	OD	0.0560	11
I	5212	CONTROL PAN	1R	1	142640	OG	0.0280	11
I	5222	TRANSDUCER	1R	1	859860	OD	0.1485	11
I	5232	BOMB RCK (RH)	1R	1	329400	OG	0.6563	11
I	5242	BOMB RCK (LH)	1R	1	329400	OG	0.6563	11
I	5252	VALVE ASSY	1R	1	324690	OZ	0.0350	11
I	5262	SONO FARNG	1R	1	507190	OG	0.0233	11
I	5272	HARNESS ASSY	1R	1	369180	OZ	0.0285	11
I	5282	MANIFOLD ASSY	1R	1	96000	OZ	0.0336	11
I	5292	BASE ASSY	1R	1	102326	OZ	0.0168	11
I	5302	COVER ASSY	1R	1	68784	OZ	0.0168	11
I	5312	APU	1R	1	9485000	OG	0.6096	11
I	5322	FUEL PUMP	1R	1	290000	OG	0.1021	11
I	5332	ACCEL CONT AS	1R	1	416962	OG	0.0186	11

I	5342	BYPASS START	1R	1	154136	OG	0.0093	11
I	5352	COMB. LINER	1R	1	391818	OG	0.1482	11
I	5362	VALV,OVRSPD D	1R	2	343176	OD	0.2100	11
I	5372	PUMP,FUEL	1R	2	256354	OD	0.0336	11
I	5382	RADIAL DRVSFT	1R	2	75817	OZ	0.0420	11
I	5392	CABLE,GREEN	1R	2	230569	OG	0.1680	11
I	5402	COOLER,OIL	1R	2	266563	OG	0.0840	11
I	5412	HISTORY RE	1R	2	944393	OD	0.0560	11
I	5422	VALVE,A	1R	2	749412	OD	0.4200	11
I	5432	ECU	1R	2	2685400	OD	0.8400	11
I	5442	HMU	1R	2	6003832	OD	0.4200	11
I	5452	INDICATOR	1R	4	20100	OZ	0.1680	11
I	5462	LEAD,IGN	1R	2	19432	OZ	0.0420	11
I	5472	LEAD,IGN	1R	2	23125	OZ	0.0420	11
I	5482	PLUG,BORESCOP	1R	2	2898	OZ	0.2800	11
I	5492	OIL TEMP SNSR	1R	2	17439	OZ	0.0933	11
I	5502	FUEL PRES SEN	1R	2	53529	OZ	0.1050	11
I	5512	EXCITER	1R	2	368363	OG	0.0420	11
I	5522	HOSE, P3	1R	2	45002	OZ	0.0840	11
I	5532	PUMP,LUBE	1R	2	231793	OD	0.0840	11
I	5542	SENSR,SP&TORQ	1R	2	183859	OG	0.0420	11
I	5552	PLUG, IGNITER	1R	4	36290	OZ	0.1201	11
I	5562	SENSR,OIL PRS	1R	2	112062	OZ	0.1050	11
I	5572	BLOWER	1R	2	487939	OD	0.1680	11
I	5582	CABLE,BLUE	1R	2	189830	OZ	0.0560	11
I	5592	HARN,THRMO	1R	2	361064	OG	0.0840	11
I	5602	CABLE,YELLOW	1R	2	576528	OZ	0.0560	11
I	5612	OIL FLT ELMNT	1R	2	12964	OZ	7.0000	11
I	5622	FUEL FLT ELMT	1R	6	20285	OZ	5.6000	11
I	5632	ENGINE	1R	2	60300000	OG	0.9722	11
I	5642	INJECTOR	1R	2	396600	OD	5.0299	11
I	5652	CHIP DETECTOR	1R	2	54936	OZ	0.1680	11
I	5662	ALT. STATOR	1R	2	267596	OZ	0.0672	11

APPENDIX C
A-,I-,L- AND J-CARD FORMATS

The computer card formats provided in this appendix allow the reader a look at the previously described data cards. The A-card and L-card provided in Figure C.1 provide the benchmark entries as used in this study for an availability constrained optimization. Three benchmark I-cards are provided as well as the first benchmark J-card.

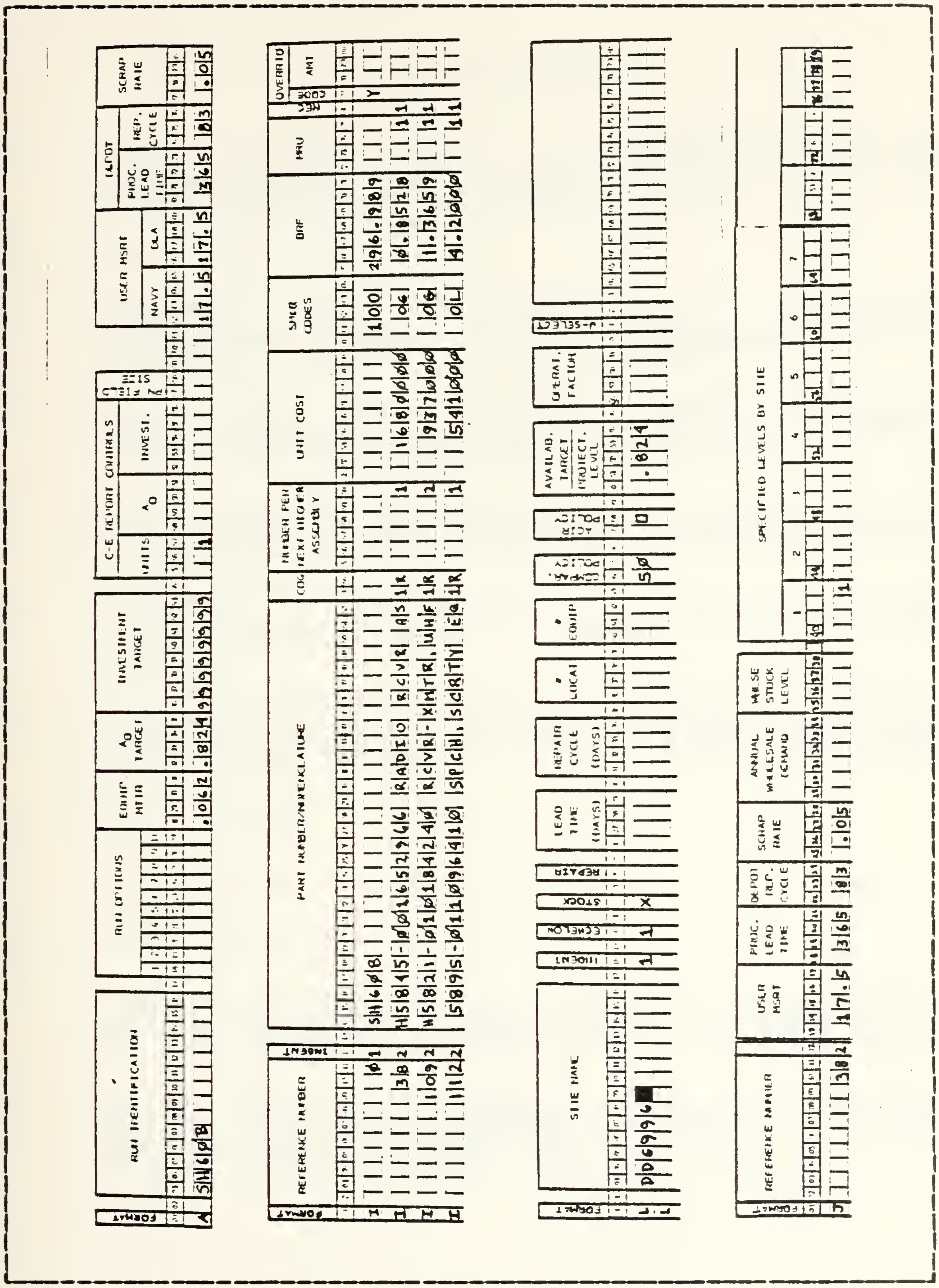

Figure C.1 A-, I-, L-, and J-card Formats.

LIST OF REFERENCES

1. CACI-Inc Federal, ACIM: An Availability Centered Inventory Model, User's Manual, Release 1.0 CACI-Inc Federal, pgs. A-2,A-3, Dec 1981.

2. Ibid, pg. 6

3. Richards, F.R.; McMasters, A.W., Wholesale Provisioning Models: Model Development, Naval Postgraduate School, pg. 56-57, September 1983.

4. Naval Supply Systems Command, Supply Management Program Standard Data Element Dictionary, NAVSUP Publication 508, pg. 3-108, Mar 1976.

5. Clack, A.J., Common Item Problems in the Operation of the Optimal A Inventory and Allocation Models. CACI-Inc Federal, pg. 1, Aug 1978.

6. Evanovich, P. and Measell, B., The Availability Centered Inventory Model: A Review, CNA, pg. 5, Dec 1982.

7. Naval Sea Systems Command, Availability Centered Inventory Rule (ACIR) Shipboard Allowance Development Procedures Handbook, pg. D-10, NAVSEA TL-441-AA-HBK-010, 1982.

8. Ibid., pg. 20

9. Ibid., pg. 27

10. Ibid., pg. C-13

11. Naval Sea Systems Command, (draft copy), Availability Centered Inventory Model (ACIM) Consumer Level Allowance Development Handbook, pg. III-17, May 1983.

12. Watras, Henry J., Combining a Level of Repair Model with an Availability Centered Provisioning Model for Logistic Support Analysis, pgs. 110-111, M.S. Thesis, Naval Postgraduate School, September 1983.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
3.	Professor Dan C. Boger, Code 55Bk Naval Postgraduate School Monterey, California 93943	2
4.	Professor F. Russell Richards, Code 55Rh Naval Postgraduate School Monterey, California 93943	2
5.	CACI, Inc. Federal Operations and Management Analysis Department 2361 Jefferson Davis Highway ML101 Arlington, Virginia 22202	1
6.	Lt. Henry J. Watras, USN Air Department USS J.F. Kennedy, CV-67 FPO New York, New York 09501	1
7.	Lt. James A. McDonell, USN SMC 2113 Naval Postgraduate School Monterey, Ca. 93943	8